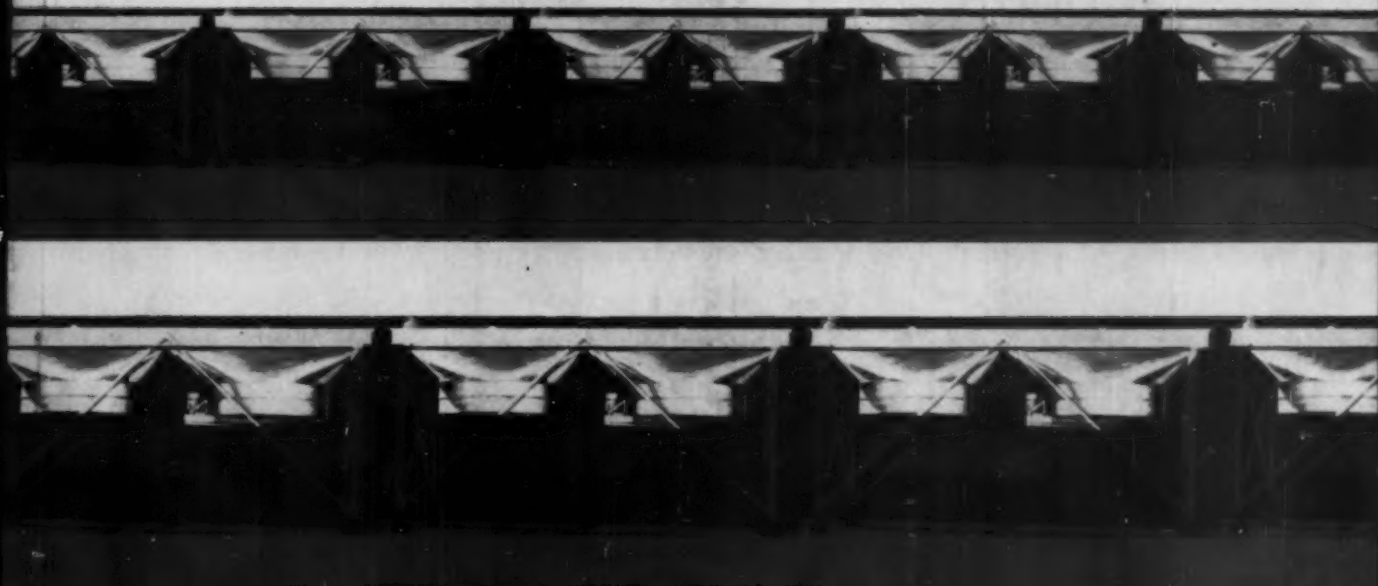
CEP

CHEMICAL ENGINEERING PROGRESS

APRIL 1959



new economies for process industries

Air cooled heat exchange . . . page 37

PLUS: Air pollution abatement . . . Statistical strategy in chemical experimentation . . . In-plant pollution control . . . Solar space cooling . . . Ethylene storage . . . Future of computer control.

CEP

CHEMICAL ENGINEERING PROGRESS

April 1959 Volume 55, No. 4

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Cover by *Paul Arlt*. Air-cooling unit photos from Hudson Engineering Corp.

◀ For more information, circle No. 6

.... in this issue

(Continued on page 5)

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AND RECOVER PRODUCT LOSSES !

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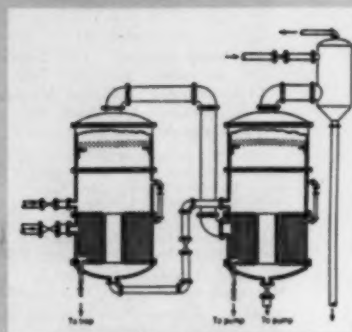

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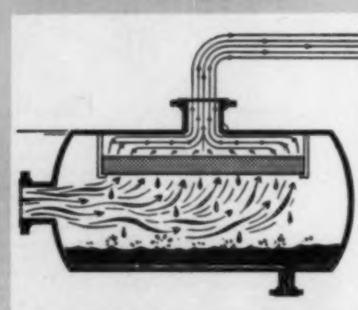

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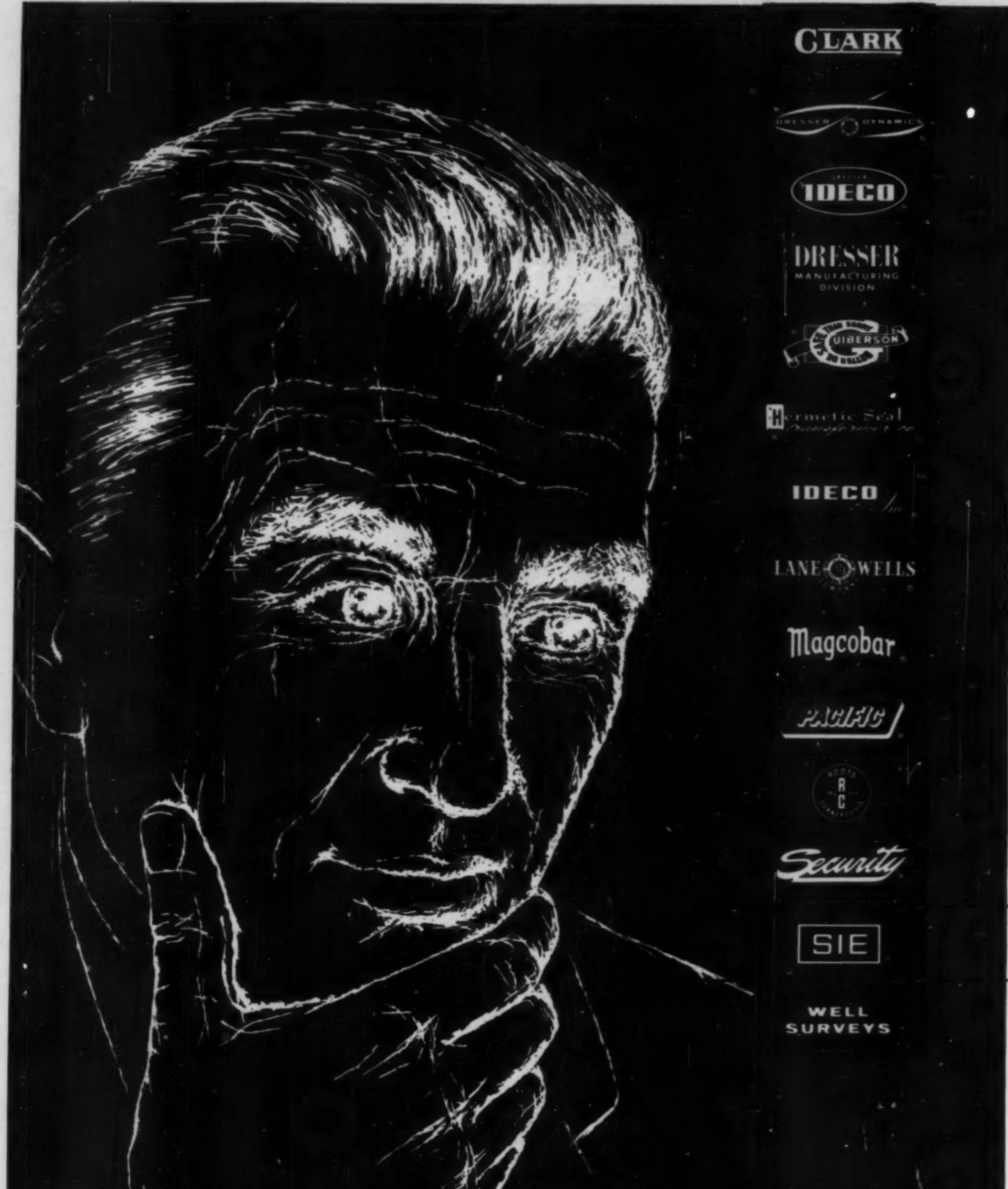
CEP .... in this issue

(Continued from page 3)

departmental features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Three votes for niobium

The Editor:

This refers to the letter from Frank T. Sisco appearing on page 6 of the January, 1959, issue concerning the name of element No. 41.

I have read a lot of the arguments back and forth as to the priority on the name for this element, and I am satisfied that the International Union had good reasons for finally recommending *niobium*. I think further that since most of our A.I.Ch. E. members are connected with the chemical industry, and as the A.C.S. is adopting niobium, our readers will be served best by continuing that usage.

I think that the A.I.M.E. if they choose to adopt in their own publications a non-standard *name* for the element, could at least choose, as the A.C.S. did in the case of tungsten, to accept the I.U.P.A.C. *symbol* for it just as they would the agreed-upon atomic weight. In English-speaking countries we habitually talk about *tin* with the symbol Sn (stannum), and *antimony*, symbol Sb (stibium). The A.I.M.E. could refer to *columbium*, symbol Nb (niobium), *if* this suited their preference.

THOMAS H. CHILTON

E. I. du Pont de Nemours
Wilmington, Del.

THE EDITOR:

In the January issue of CEP there is a letter from Frank T. Sisco on the subject columbium vs. niobium. There is nothing tragic if an element has two different names in various countries. So far as the record goes, it is only in the English-speaking countries where this confusion exists. This is not a unique occurrence; for example, wolfram vs. tungsten.

The facts are as follows: "In 1801 Charles Hatchet when making an analysis of a mineral which he found in Connecticut, U. S. A., discovered a new element which he named 'columbium.' In 1802 Gustav Ekeberg discovered in the mineral columbite the element tantalum, which name he adopted from Greek mythology because the characteristics of tantalum oxide were said to be comparable with the 'Torture Tantalus' because of its behavior in an excess of acid.

"As late as 1809 Wollaston attempted to prove that the elements tantalum and columbium were identical. It was not until 1844 that Heinrich Rose actually succeeded in separating these elements, and adopted the name 'niob' (niobium), also from Greek mythology, for the daughter of Tantalus whose name was Niobe."

From the above facts, it will be seen that Hatchet did not discover the pure element niob (niobium) but merely a mixture of tantalum and niobium, and it was not until the year 1844, through the work of Heinrich Rose, that the two elements were separated and their characteristics, which in many respects are similar, recorded. This is not in any way an attempt to deprecate the work of Hatchet, who unquestionably first made the discovery, but it was those who followed to confirm his work who found that he had really discovered "twins," for which of course two names were necessary.

The question as to correct usage can be debated *ad infinitum*, but we hold that ultimately these not identical twins will be called niobium and tantalum for obvious reasons. If by someone calling it columbium the use and application of this element will be increased, I can see no reason for worrying about such an unimportant matter.

ARTHUR LINZ

New York, N. Y.

THE EDITOR:

I read with great interest Frank T. Sisco's letter to Chemical Engineering Progress. Being both a member of the A.I.M.E. and A.I.Ch.E., and at the same time an abstractor for Chemical Abstracts, I feel I have a right to express an opinion on the matter.

Sometimes, I think, we are too self-righteous in America and do not enter into the spirit of give-and-take that is required for international cooperation in scientific matters. When Dr. Crane in representing the U. S. accepted niobium in preference to columbium he must have been aware that more countries had been using this name regardless of the original discoverer. England, Russia, and Germany had been using Nb. In the case of tungsten only the Germans had been using the name wolfram, while the French and Russian names are based on the same word roots as tungsten and the British also use tungsten.

I see nothing wrong with the chemical engineering profession using the same standard as the chemists in spite of a unilateral declaration by the A.I.M.E. Even Dr. Bruce Gonser, who certainly is a top metallurgist, uses niobium (columbium) in a very recent article on: *Progress in the Newer Metals.*

JACK M. NOY

Quebec Iron & Titanium
Sorel, Quebec, Canada

Standard classification and retrieval

Over the past year considerable interest has been exhibited in the technical magazines and by members of the American Institute of Chemical Engineers and others in the possibility of developing a standard method or system for the classification and future retrieval of technical data and information.

At the Institute's "Golden Anniversary" meeting in Philadelphia in June 1958, this interest was heightened by the delivery of several papers on the subject. At the request of several Members of the Institute the Standards Committee agreed to investigate the need for such a standard system in the chemical engineering profession and the chemical industry.

The Standards Committee, therefore, has set up a subcommittee under the chairmanship of Charles M. Cooper to determine and recommend the need for such a standard system and, if need is found, to recommend whether the A.I.Ch.E. should undertake the development of the standard or propose other means of having a uniform system developed that would meet the requirements of the entire technical field for classification and retrieval of technical data and information.

The subcommittee is now in course of organization under Mr. Cooper's chairmanship, and will report from time to time to the Standards Committee as to its progress and for advice and assistance as may be felt necessary.

Members of the Institute and other interested parties may communicate with the Chairman of Standards Committee: J. C. Lawrence, P.O. Box 194, Moylan, Pa. or Charles M. Cooper, E. I. du Pont de Nemours & Co., Louviers Bldg., Wilmington 98, Del.

J. C. LAWRENCE, *Chmn.*
A.I.Ch.E. Standards Committee


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about our authors

Bob G. Perkins (*Heat Removal—With Water or Air?*), has been engaged in design and operation of air-cooled heat exchangers in a number of different services. Perkins is with Celanese Corp. of America at Pampa, Texas, where he also functions as "trouble-shooter" on plant operational problems, in addition to working on economic evaluations.

Authors: Perkins, Young, Katz.

According to **Edwin H. Young**, who collaborated with **Marvin L. Katz** on *Performance of Integral Finned Duplex Tubes*, the investigation is being continued, with equipment modified to permit accurate measurement of bond resistances at elevated temperatures rather than at a standard reference temperature. Katz and Young have been working together for the past several years on the finned tube heat transfer project at the University of Michigan Research Institute, Young as supervisor of the project, and Katz on a part time basis.

L. to r. Nakayama and Thomas

John W. Thomas (*Air vs. Water Cooling—Cost Comparison*), lead-off contributor to the air-cooled heat transfer section in this month's issue, specializes in work on heat transfer equipment for Standard Oil of Ohio.

E. U. Nakayama (*Optimum Air Fin Cooler Design*), has a wide acquaintance with natural gasoline plant maintenance and operations, both in mechanical design and field process engineering, and development and test work. He is now with Phillips Petroleum.

S. L. Andersen (*Statistics in the Strategy of Chemical Experimentation*), is connected with the Engineering Service Division of DuPont at Wilmington, Delaware.

Lauren B. Hitchcock (*Air Pollution Abatement — A Management Problem*) assisted in the organization and

continued on page 12

For more information, turn to Data Service card, circle No. 51

about our authors

from page 10

direction of the Air Pollution Foundation as its first president. Active in A.I.Ch.E. for over twenty years, Hitchcock was a founder and first president of the Commercial Chemical Development Association. He is a partner in the chemical engineering firm, Hitchcock Associates.

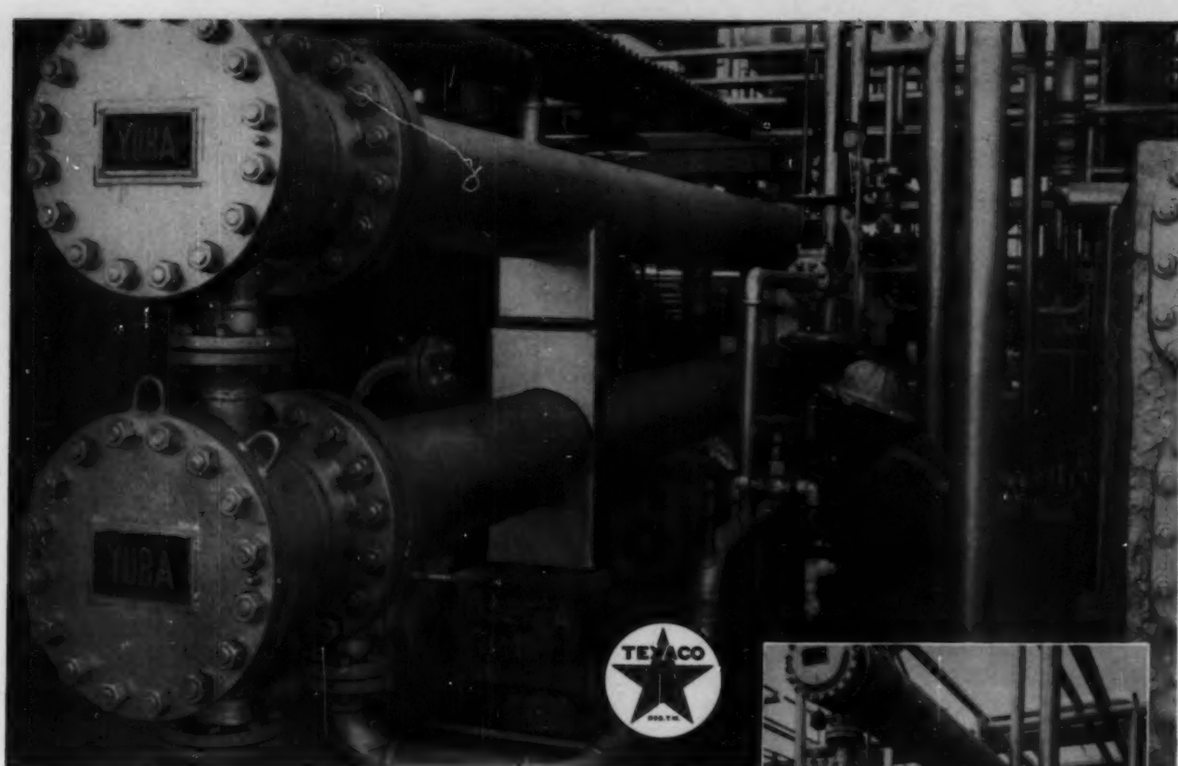
Both **H. W. Bialkowsky** and **Joseph C. Brown, Jr.** (*In-Plant Pollution Control in Pulp and Paper Industry*), have been with Weyerhaeuser Timber for over ten years. Bialkowsky is now director of research, Pulp Division, and Brown is general manager of North Carolina Pulp Co., a subsidiary firm.

Bialkowsky, Scheline, Hitchcock.

W. H. Litchfield, W. H. LeGrand, Morgan Martin, D. C. Scheline and **V. N. Hurd** (*Distribution and Storage of Ethylene*), are all associated with the Petrochemicals Department of Gulf Oil. Hurd is director of the Petrochemical Development Department at Pittsburgh, where Scheline is also located. Martin is with Gulf Refining at Houston, while Litchfield and LeGrand are at Port Arthur and Houston, Texas, respectively.

Authors: Löf, Duffie, Chung.

All three authors of *Solar Space Cooling*, **Raymond Chung, John A. Duffie** and **G. O. G. Löf**, are prominent in the field. Chung has been a member of the Solar Energy Laboratory since 1955. Duffie is project associate, University of Wisconsin, Solar Energy Research Program. He is editor of and contributing author to "Solar Energy Research". Duffie is also assistant director of the University's Engineering Research Station. Löf, a consulting chemical engineer in Denver, Colorado, has specialized in solar energy development work for 15 years.



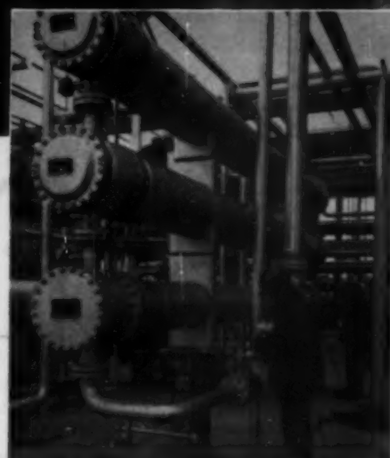
52 YUBA Heat Exchangers

perform in eight different critical processes at The Texas Company's newest refinery

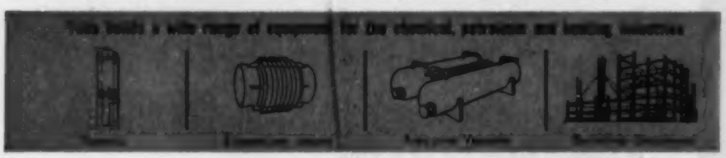
Newest of Texaco's 12 refineries in the United States, the 45,000-barrel Puget Sound Works in Washington went on stream the end of 1958.

Producing a full line of petroleum products from regular gasoline to jet fuels, this plant requires precision equipment throughout a number of different processing units. 52 precision-built Yuba Heat Exchangers, with a total of 72,991 sq. ft. of heating surface, are at work in eight of these critical processes, efficiently performing their required jobs in a temperature range of 75° to 600° F, and pressures up through 650 psi.

Here is another example of how Yuba works with the petroleum and chemical industries to achieve the optimum combination of heat economy, efficiency, and resultant lower costs. For your next heat exchanger job call on Yuba. Rating and designing services, as well as complete manufacturing facilities, located both East and West to serve you best.



Two of the four Yuba Heat Exchangers (top) in the Cat Poly Unit. The three units above are in the plant's Alkylation Unit. Below: aerial view of the refinery on its 833 acre tract. Yuba Heat Exchangers can be equipped with exclusive *Multilok Closures* for higher pressures through 6,000 psi, and temperatures to 1200° F.



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Ten ways to conserve engineering manpower

Out of a series of conferences organized by the President's Committee on Scientists and Engineers have come a host of suggestions on ways to coordinate and stimulate the nation's efforts to meet growing needs for scientific and engineering manpower. A total of nineteen local "utilization" conferences have been held throughout the U. S. between September, 1957 and December, 1958. Participating have been representatives of Government agencies, industry, professional organizations, academic institutions. The majority of the conferees, however, came from top or middle management.

Specific suggestions, outlined by William G. Torpey, of the Office of Civil and Defense Mobilization, speaking at the recent A.I.Ch.E. National Meeting in Atlantic City, included:

Use of position guides. Careful evaluation of the actual duties of individuals in professional positions. This can be facilitated by development of a detailed job description for each scientific and engineering position, and a plan for periodic formal analysis of the specific tasks of the individual scientist and engineer.

Engineering apprentice program. Technicians can be trained with the objective that they ultimately become professional engineers.

Design work. The use of student assistants for drafting work is often a practical method to free the engineer for professional duties.

Use of computers. Conservation of professional time through the use of computers is growing.

Tuition refund program. Many organizations have established tuition refund programs to provide advanced knowledge for optimum performance by scientific and engineering employees.

Upward communication. Any organization, particularly one employing professional personnel, functions best when each individual has maximum access to the thinking of his superiors, as well as of his subordinates. All obstacles to the upward flow of information should be cleared away.

Encouragement to publish technical papers. Companies can organize technical publication committees to provide such encouragement and coordination.

Employer assistance to publish technical books. Publishing contracts, royalty agreements, can be negotiated with the assistance of company legal staffs, and stenographic, manuscript preparation services may be provided by the company.

Pre-selection of technical material. Some companies have found that a considerable amount of professional time can be saved if technical material is predigested and "spoon-fed" to its professional members. Such pre-selection can often be performed by non-technical personnel.

Recognition. A program of equitable recognition for scientists and engineers is an essential to retain such personnel, and to develop the maximum potential of the scientific and engineering staff.

It has been stated, according to Torpey, that if we, as a nation, could improve the utilization of our current supply of scientists and engineers by only five percent, we would thereby add to the effective professional force as much as all the college graduates who will complete their training in one year.

Kellogg wins first round in methanol plant suit

The New York Supreme Court has granted motions by M. W. Kellogg to compel arbitration of multi-million-dollar claims arising out of construction of a methanol plant in Texas City, Texas, for Monsanto and Heyden-Newport Chemical. In ruling against Monsanto and Heyden, Supreme Court Justice Thomas A. Aurelio denied a motion by the latter two companies which sought to restrain Kellogg from seeking arbitration.

$77 million "Minuteman" contract to Thiokol

Research and development for three stages of the Minuteman solid propellant rocket propulsion system will be carried out by Thiokol Chemical, under a $77 million Air Force contract.

Rocketry—chemical engineering challenge

A highly-engineered chemical plant, which under ordinary conditions would cover about ten acres and occupy three large buildings, must now be compressed into a cylinder some six feet in diameter and eighty feet high—this is the challenge confronting chemical engineers in the design of liquid-fueled missiles, said Rocketdyne's chief engineer, T. Dixon, speaking at a panel discussion on *Rockets, Missiles, and Satellites* at the recent A.I.Ch.E. National Meeting in Atlantic City.

The classical chemical engineering unit operations are still valid in this new field, continued Dixon, but the amount of compression required introduces entirely new factors of concept and design. Fluid flows up to 30,000 gallons per minute must be handled by very small, compact pumping units; the flow must often be started in a quarter of a second, and stopped in from one to four milliseconds. Mixing operations must be carried out at unheard-of rates in extremely small volumes. Heat transfer equipment must be specially designed to handle gas temperatures in the range of 6,000 to 8,000°F. and to control with extreme accuracy the boiling point of the liquid fuels. Materials handling and loading of the missiles also present new and hitherto "impossible" problems.

The rocket and missile industry, according to Dixon, is not undergoing any serious shortage of chemical engineers since, in his opinion, some of the best brains in the field have gravitated in this direction for the opportunity to work on the frontiers of engineering achievement.

Solid-fueled rockets can, in the future, be expected to share the lime-light with the liquid-fueled species, brought out H. W. Ritchey, vice-president of Thiokol Chemical; they also present challenging problems to the chemical engineer. According to Ritchey, the solid variety should logically find its place in the "booster" stage of the big missiles, while liquid-fueled units should be better adapted to the later stages. This he pointed, out, is at variance with current practice. There is, said Ritchey, no practical limit to the size of solid rockets; they could conceivably be built and successfully fired up to about three hundred feet long, based on present concepts. Even the transportation problem poses no obstacle since it would be entirely feasible to mix and cure the solid core in an installation at the launching site.

Summed up Dixon—"We have used up the knowledge of the last century." It remains for today's engineers to find new combustion processes, new methods of heat transfer, new systems of control.

New additive claimed to up octane ratings

"The most important development in the anti-knock additive field since the introduction of tetraethyl lead 36 years ago," says The Texas Co. of their new "TLA" (Texaco Lead Appreciator). The new additive should mean lower costs for the consumer, says Texaco, since adding TLA costs less than increasing octane by refinery methods, particularly at high octane ratings.

AEC to negotiate fuel cycle development contracts

Twenty-four proposals from eighteen firms have been chosen by AEC as a basis for negotiation of contracts to do research and development work in private facilities on AEC's fuel cycle development program.

Du Pont collects $1,500,000 war claim from Soviets

The Soviet Union has paid Du Pont $1,500,000 in settlement of claims arising out of technical information on synthetic rubber supplied to the Soviet Union by Du Pont during World War II. Some industry circles look on the move as aimed at the possibility of resumed dealings between Soviet industry and Du Pont—an interpretation lacking, however, any substantiation on the part of Du Pont.

Triple play in urea

From Pechiney to Foster Wheeler to Grace. Pechiney of France will license to Foster Wheeler its total recycle urea process; licensees will benefit, under a special arrangement, from five years' operating experience of W. R. Grace, one of the first licensees of the Pechiney process in the U. S.

Does Diversification Pay Off?

"In analyzing the chemical process industries, those companies that have primarily 'stuck to their knitting' and integrated vertically, rather than diversified horizontally, have fared better than the strictly acquisition-minded companies. While there are exceptions to the rule, the burden of evidence supports the merit of this concept and also the reverse process of selling off assets that do not fit into an integrated program."

Source—research study by Smith, Barney & Co., N. Y. Stock Exchange firm. *Subject*—the recent CCDA Annual Meeting in New York's Statler Hilton which considered *Diversification in the Chemical Industry*.

Many viewpoints

Opinions brought out in panel discussions at the CCDA meeting ran the gamut. "Dow Chemical has depended chiefly on internal diversification for its growth," said J. C. Van Horn, Dow's manager of technical service and development. An internal diversification program can best be based on areas of inherent strength within a company, he added.

Looking at the other side of the coin, a company may be too diversified, brought out C. E. Waring, W. R. Grace vice president. A limit to the amount of diversification practicable in any company may be set by the number of fields in which management can be expected to be knowledgeable, said Waring. Joint operations with other companies, he continued, must be big enough to justify the resulting diversion of management talent. Grace's present collaboration with Pechiney of France to build a high-purity silicon plant in Puerto Rico, however, has so far worked very well indeed, added Waring.

"The basic raw material is ideas," said C. W. Walton of Minnesota Mining and Manufacturing, advocating the building up of "quasi monopolies" through a strong patent position. Unusual techniques, and the creating of new products, often bring unusual profits, he said.

People are the key

"There have been less than about ten percent of 'divorces' among recently-merged companies in the chemical field," claimed L. B. Hitchcock of L. B. Hitchcock Associates, who moderated a panel discussion on *Diversification from Without—The Management of Acquisitions*. What factors lead to success in the management of newly-acquired companies? People, in the opinion of all the panelists, are the most important element in making a merger work. People generally wish to continue doing what they have been doing, emphasized C. F. Prutton, Food Machinery and Chemicals V. P. Therefore, he said, it is always advisable to make a most thorough examination of the personalities of the staff of the company being considered for acquisition, in particular of top management people. According to Prutton, any drastic changes should be made as early as possible, but only after sufficient study of the persons involved (Off-the-cuff estimates by several of the panelists as to the percentage of management personnel usually replaced in a merger situation ran to about one or two percent).

Washington Notes

Business expects to spend $32 billion on new plant and equipment in 1959, about $1.25 billion (or 4%) more than last year, according to the annual survey conducted jointly by the Securities and Exchange Commission and the Department of Commerce. . . . A cost-reimbursable negotiated contract, not to exceed $50,000, has been awarded by the Office of Saline Water to W. L. Badger & Associates, Ann Arbor, Mich., for preliminary design of a one million gallon per day saline water conversion demonstration plant. . . . First of three solar stills to be tested and developed by Battelle Institute has been completed at a seashore site near Port Orange, Florida. . . . Atomic Fuel Corp., Japan, has dedicated the Tokyo Uranium Refining Plant for production of reactor-grade UF_4 and vacuum-cast uranium metal. The unit, designed by Weinrich & Associates of Washington, D. C., is said to include the first commercial application of the Higgins-type moving-bed ion exchange column and of the electrolytic uranium reduction cell. . . . The Advanced Research Projects Agency, according to Dept. of Defense Directive 5105.15, "will be separately organized within the Dept. of Defense under a Director of Advanced Research Projects appointed by the Secretary of Defense." . . .

J. L. Gillman, Jr.

Too much paper work?

The scientist in industry spends an average of 16⅛ hours per week in scientific communication; 15.9 hours per week in other scientific activity; 6.7 hours per week in business communications; and 51.1 hours per week in personal and social activity. Thus, the scientist spends 23.2 hours per week purely in communication, as opposed to 15.9 hours in actual scientific work in the laboratory.

These figures are the result of a survey just completed by the Operations Research Group at Case Institute of Technology, under R. L. Ackoff. The study was sponsored by the Office of Scientific Information of the National Science Foundation. Basis for the conclusions was a sample of 1,500 scientists in organizations employing 5 or more scientists and located in one of the 150 largest metropolitan areas. Included in the sample were 45 industrial organizations and 5 universities. About 25,000 separate observations of the 1,500 scientists were made.

The survey brought to light several interesting correlations:

As the number of secretaries and administrators for each scientist in the research group increases, the percentage of time that the scientist spends in using equipment decreases.

Where salaries paid to other personnel increase compared to scientists', salaries increase, the amount of time spent by scientists with equipment increases, and the amount of time in business communication decreases. Also, as the value of the physical facilities for the scientist increases, the amount of his business communication decreases.

As more literature becomes available to an individual scientist, through company libraries and routine circulation to his desk, he spends more time reading the material. Parenthetically in the case of chemists, it was found that nine out of several thousand journals accounted for half of the articles read by the chemists.

What is to be done?

Obvious need, says the Case report, is to improve the efficiency of the time spent by scientists in reading. The OR group came up with three suggestions:

Enable scientists to read articles more quickly, either by improving their readability without increasing their length, or by reducing their length by eliminating unnecessary material.

Enable the scientist, once he has started an article, to determine more quickly whether it is relevant; this might be done by including a summary or digest at the start of each article.

Enable the scientist, if his interest is general rather than specific, to get the essence of the article without having to go through all the details.

Recommendations of the Case Study Group included extension of the survey to find out if the conclusions are valid for a larger and more diverse sample of scientists, and continued research on publication practices to improve readability.

A.I.Ch.E. nears Member Gift Campaign goal

The A.I.Ch.E. member contribution toward the United Engineering Center soon to rise in New York is almost completely subscribed—latest figures show a total of $285,000, or 95% of the A.I.Ch.E.'s $300,000 quota.

Union Carbide to build ethylene oxide plant in Italy

An ethylene oxide and derivatives plant will be erected at Priolo, Sicily, by Celene S.p.A., jointly owned by Union Carbide and Edison of Milan. Annual capacity is expected to reach 12,000 tons by mid-1960.

EJC to sponsor international student exchange

Engineers Joint Council has become the sponsor for the U. S. Committee of the International Association for the Exchange of Students for Technical Experience (IAESTE).

First synthetic ammonia plant for Peru

Peru's first synthetic ammonia plant, designed and build by Montecatini of Italy, is scheduled for startup this month. Owned and operated at Callao by Fertilizantes Sinteticos, S.A., the plant will turn out ammonium sulfate, ammonium nitrate fertilizers, anhydrous ammonia, nitric acid, ammonium nitrate. Cost: about $10 million, financed half by private Peruvian capital, half by an Italian bank loan.

U.S.I. CHEMICAL NEWS

Apr. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1959

Soluble Sodium Complexes Prove Valuable for Wurtz Reactions and Metalations

It has been found that some aromatic hydrocarbons will form highly reactive soluble complexes with sodium in certain "active" ethers. These complexes are very useful for carrying out many metalation reactions and condensations of alkyl and aryl halides (Wurtz reactions).

Among the hydrocarbons found useful are naphthalene, diphenyl, the terphenyls and anthracene. The "active" ethers include dimethyl ether, methyl ethyl ether, dimethyl ether of ethylene glycol and tetrahydrofuran.

By proper choice of hydro-

MORE

Armed Forces Outline Still-Unsolved Chemical Problems; Call for Help

The National Inventors Council recently published a report titled "Inventions Wanted by the Armed Forces," discussing military needs for certain types of materials which cannot as yet be supplied for technological reasons. The report calls for the chemist's assistance in providing:

(1) waterproofing compound for gages that will be flexible from –20 to 140°F and bond to anything.

(2) metal-to-metal adhesive, good up to 600°F, with a shear strength of 2,500 psi minimum.

(3) adhesive for explosives which can be applied down to –40°F; hold a 2½-lb. block of explosive on a vertical square for 60 days, using about 15 sq. in. of block surface; support the block on a variety of dirty, wet or uneven vertical surfaces.

(4) easy method for growing large, single silicon crystals of uniform lifetime, resistivity and dislocation density.

(5) quartz crystal units in the 1-100 mc range, able to operate from –55 to 90°C without more than 5 ppm deviation from nominal frequency.

(6) method of making colored smokes which would reduce the present 80-90% dye loss due to decomposition.

Copies of the report can be obtained at no charge from the National Inventors Council, U. S. Dept. of Commerce, Washington 25, D.C.

New Process for HCl Said to Yield Economies

A preliminary German patent, DAS 1-035-626, claims that hydrochloric acid can be made very economically in a plant consisting of a single tower lined with graphite-based, corrosion-resistant material.

As described, the process consists of burning hydrogen and chlorine in a bell-shaped reaction chamber at the bottom of the tower. The resulting acid, as a gas, passes through slits in the chamber and travels up through an absorbent, noncorrosive packing. Water or dilute acid drips down, cooling the tower walls and the reaction chamber, and is concentrated at the same time.

Ethylene Is Basic Raw Material For Giant Chemical Complex

U.S.I. Uses Versatile Chemical 6 Ways: to Make Alcohol, Polyethylene, Ethyl Chloride, Ether; for Refrigeration In Its Own Manufacture; for Sale in Cylinders.

Ethylene is probably the most valuable petrochemical building block available to the CPI today. Almost four billion pounds were produced and used in 1957, and it is estimated that production capacity last year was about five billion pounds. At Tuscola, Ill., a huge complex of chemical plants — turning out a wide variety of large-volume products — has been erected on the foundation of a plentiful ethylene supply. Here, several natural gas pipelines from the Southwest join at a compressor station which feeds extraction and fractionation facilities. The ethane fraction from these facilities, converted to ethylene, becomes the "jack-of-all-trades" at the Tuscola complex.

The values of ethylene are its low cost and its ability to polymerize or react by addition with simple and inexpensive materials, such as hydrochloric acid, oxygen and chlorine, to yield extremely useful intermediates or end products. At Tuscola, ethylene is used for synthesis of polyethylene, ethyl alcohol, ethyl ether and ethyl chloride. A small portion is employed in the ethylene purification plant for refrigeration. It is also bottled under pressure in steel cylinders and sold as a ripening and conditioning agent for fruits and vegetables, as a chemical raw material, and as a refrigerant. (A new technical data sheet gives commercial specifications for U.S.I. refined ethylene, properties of the pure compound, and use data. Copies can be obtained upon request on company letterhead.)

100 Million Pounds of Polyethylene

Of the 500 tons of ethylene produced at Tuscola each day, a third is polymerized to polyethylene. Ethylene raw material for this process is brought to a very high purity in a separate step which employs the ethylene gas itself as a refrigerant. Converting ethylene to polyethylene requires two steps. The gas is compressed under extremely high pressure and pumped into the polymerization reactor, where it is held at high pressure and moderately high temperatures. A catalyst is added to start the reaction. The polyethylene formed flows to a separation system where unreacted gas is removed. Low and intermediate density resins are produced by this process at Tuscola's 100-million-pound-per-year polyethylene plant.

U.S.I. ethylene unit supplies 100-million lb.-per-year polyethylene plant at Tuscola, Ill.

Ethanol, Ether and Ethyl Chloride

Recycled ethylene, as well as fresh make-up from the ethylene unit, feeds into the ethyl alcohol facility where it is absorbed in sulfuric acid and then hydrolyzed under controlled con-

Ethylene in cylinders is sold by U.S.I. for food processing, as a refrigerant, and as a chemical raw material.

ditions to yield 190-proof and anhydrous alcohol. This synthetic alcohol plant is among the country's largest and supplies alcohol raw material for a large segment of the American chemical industry. Ethyl ether is a by-product of the same process. In another plant, by reaction with hydrochloric acid, more ethylene is converted into ethyl chloride — sold for production of tetraethyl lead and other products.

Advantages of Integrated Production

The Tuscola operation could, if the demand arose, produce other ethylene derivatives such as ethylene oxide, ethylene dichloride and ethylene chlorohydrin. The integrated plant permits great economies in the production of all derivatives. Ethylene not used in making other U.S.I. products is sold in cylinders.

Over the last few years, as the market for polyethylene has soared, ethylene production capacity at Tuscola has been doubled. If activity within this integrated chemical complex is any indication, the demand for ethylene as a chemical building block should certainly reach and exceed the 6.5-billion-pound mark now being predicted for 1965.

Apr. ★ **U.S.I. CHEMICAL NEWS** ★ 1959

CONTINUED *Sodium*

carbon and active ether, reaction conditions may be so chosen that no interference from the solubilizing components will be noted. The rate of formation of these soluble sodium carriers is much more rapid and complete with sodium dispersions than with massive sodium. Sometimes dispersions are made directly in these aromatic hydrocarbons.

A soluble complex will transfer sodium from the carrier to another organic compound with the regeneration of the hydrocarbon carrier. The hydrocarbon then promptly solubilizes additional sodium. Thus only a catalytic amount of hydrocarbon is required.

As an example of this very useful technique, bibenzyl in dimethyl ether can be prepared from benzyl chloride using a sodium dispersion solubilized in naphthalene and terphenyl. The reaction is demonstrated by the equation:

$$\underbrace{2\phi CH_2Cl}_{\text{benzyl chloride}} + 2\,Na \rightarrow \underbrace{\phi CH_2CH_2\phi}_{\text{bibenzyl}} + 2\,NaCl$$

Details of this preparation are given in U.S.I.'s brochure "Sodium Dispersions," available on request.

Another interesting application of sodium complexes is the use of sodium and naphthalene for etching "Teflon" resin surfaces so that the "Teflon" resin can be bonded to other materials.

Experimental Fuel Cell Converts Chemical Energy Directly to Electricity

A compact, experimental gaseous fuel cell recently developed converts chemical energy from an external source into electrical energy directly and instantaneously. There are no heat engine losses, and so the cell has a theoretical 100% efficiency. In trial runs, a 24-volt cell was used successfully to light two 15-watt electric light bulbs.

The fuel cell contains electrodes and an electrolyte, and hydrogen and oxygen are used as the fuel gases. Hydrogen is catalytically ionized at the anode – releasing electrons to the external circuit – and reacts with ions in the electrolyte. Oxygen is ionized at the cathode – absorbing electrons from the external circuit – and reacts with the electrolyte to replace the ions used at the anode and to form water. As a result, electrons flow through the external circuit at a voltage characteristic of the chemical reaction—and light the lamps.

Polyethylene Reflector Used in Training Reactor

A small sub-critical reactor, with a core 10 inches in diameter by 14 inches long, is being used as a teaching aid at the University of Texas, to train future nuclear scientists in the use of radiation equipment and the characteristics of reactors.

The reactor uses two types of reflectors – polyethylene and graphite – with thicknesses varying from three to ten inches. During study, students will put a uranium core inside the reflector and add a neutron source. Although neutrons will be multiplied by the core, they will be retained by the reflector. When the source is removed, multiplied neutrons will die out. There is no danger to students, unless they come in close contact with the neutron source.

Uranium core being inserted into polyethylene reflector of training reactor at University of Texas (photo courtesy of Lockheed Aircraft).

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

Bacterial inhibitor for cutting oil emulsions and coolants now on market is claimed to extend emulsion life two to four times. Material is combination of bacteriocides thimerosal and sodium o-phenylphenate. **No. 1460**

New polyethylene tank for corrosive solutions contains inner polyethylene basket to hold parts to be dipped. Tank is 12" x 26" x 12". Basket, 6" x 24" x 3", has half-inch holes for contact between parts and solution. **No. 1461**

Instrument to measure internal corrosion and record it hourly is now available. Said to detect as little as one millionth of an inch of corrosion electronically. A dual-element probe provides the measure. **No. 1462**

Lange's Handbook of Chemistry in revised, updated ninth edition can now be purchased. New material has been added, some tables are completely rewritten, many numerical values have been changed to bring them up-to-date. **No. 1463**

Rates of rusting in different parts of country are compiled in index now available. Cities with populations over 10,000 are listed, with times to rust standard, uncoated steel test panel. Index is result of 25-year research. **No. 1464**

Heavy polyethylene coating is now being used on matched weighing papers for analytical balances. Advantages claimed include cleanliness, inertness, ease of washing contents into volumetric flask, low cost. **No. 1465**

New suction device for filling pipettes can now be obtained. Designed for operation with one hand . . . thumb presses rubber bulb at top to provide suction, forefinger operates coarse air control valve. **No. 1466**

Protective coatings are subject of new bulletin. Easy-to-read table lists each coating—its description, general use, primer, number of coats, cautions, max. use temperature, colors, surfaces for coating, wear properties, chemical resistance, method of applying. **No. 1467**

Heavy-duty polyethylene bag in 5-gallon drum being used to pack reagents such as sodium and potassium hydroxide, phosphoric acid, formaldehyde and liquid chelating agents. Package is disposable, easy to handle and store. **No. 1468**

New amphoteric surfactants now in commercial production are salts of N-alkyl beta-amino-propinates. They can be either cationic or anionic and are suggested for cosmetics, shampoos, cleaners, emulsifiers. **No. 1469**

Pays for itself in Savings!

Lapp PULSAFEEDER

CONTROLLED-VOLUME CHEMICAL PUMP

The moment your new Pulsafeeder is put into operation, you're on the way to real savings . . . savings that can eventually result in the Pulsafeeder paying for itself.

Lapp Pulsafeeder, the chemical pump with *no stuffing box,* is a piston-diaphragm pump providing *positive displacement* by a piston pumping a hydraulic medium working against a diaphragm. The diaphragm isolates the chemical being pumped from the working pump parts . . . eliminates need of stuffing box or running seal . . . prevents corrosion. Maintenance costs are reduced to next to nothing—there are practically no repairs or replacement of parts with a Pulsafeeder. You'll save, too, by elimination of product loss due to leakage or contamination. In the long run, Pulsafeeder is the safest, surest and lowest cost controlled-volume chemical pump. To prove our stand, we'll be happy to quote actual maintenance costs taken from recorded case histories.

WRITE FOR BULLETIN 440 *with typical applications, flow charts, description and specification of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Div., 3709 Poplar St., Le Roy, N. Y.*

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NO STUFFING BOX

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Metals at high temperatures, heat exchangers, fluidization, ASTM standards—subjects of new books

THE BEHAVIOUR OF METALS AT ELEVATED TEMPERATURES. Published for the Institution of Metallurgists by Iliffe and Sons, London, England, and in U. S. by Philosophical Library, New York, New York (1957), 122 pp., $6.00.

Reviewed by Donald E. Roda, Rocketdyne, Division of North American Aviation, Inc., Canoga Park, California.

The theory and principles of high-temperature metallurgy, along with the mechanical and physical properties of metals and alloys, are covered in four well-prepared articles. These were first delivered for the Institution of Metallurgists at Llandudno, England, as a series of refresher courses in October, 1956.

With so broad a subject it is possible to state only the many principles involved and not to prove or derive them. The text is illustrated and supplemented with sixty-five figures, eighteen tables, and forty-eight references. In general, the references are taken from the British literature, except in a few instances where it was necessary to go to the American literature as a source of information.

N. P. Allen covers the theory, engineering properties, and behavior of metals at elevated temperatures and discusses the principles to be followed in developing new high-temperature alloys.

G. E. Meikle deals with the materials used in airframe structures, including the light metal alloys, titanium, aluminum bronze, and low alloy steels. The percent loss of room temperature mechanical properties with increasing temperature is proposed as the best means of transmitting this information to the design engineers. This contribution concludes with a brief comparison of the structural efficiency of typical materials, the comparison taking into account density and design considerations.

L. B. Pfeil discusses the nickel and cobalt base alloys normally used for turbine blades and similar parts. Other materials for use as melting crucibles, thermocouples, heating elements, etc., at temperatures over 500° C. are considered. Requirements for corrosion resistance and principles concerning mechanical properties in this temperature range are also covered in this article.

W. E. Bardgett deals with the high-temperature steels under the heading of "steam power plants" and "gas turbine power plants." Included are carbon steels, low alloy steels, straight-chromium-type stainless steels, and the chromium - nickel - niobium austenitic stainless steels.

This work is a summary of the latest information in mechanical and physical properties of metals at elevated temperature. A reading is recommended for both metallurgists specializing in high-temperature properties of metals and engineers engaged in the design of elevated temperature equipment.

COMPACT HEAT EXCHANGERS, W. M. Kays and A. L. London, McGraw-Hill Book Co., Inc., New York, N. Y., 156 pp., $6.00.

A master reference summary of basic heat transfer and flow friction design data, containing much information heretofore available only in scattered reports and papers. It covers tube banks, (circular and flattened, with inside and outside flow), plate-fin surfaces, finned tube surfaces, and screen and sphere matrix surfaces. A chapter is devoted to basic theory of heat transfer prediction and pressure drop. Another chapter contains graphs of abrupt contraction and expansion pressure-loss coefficients for various types of heat-exchanger cores. Subsequent chapters cover such topics as analytical solutions for heat transfer and friction in smooth tubes; data for gas flow through circular tubes; and flow normal to banks of staggered circular tubes. Eighty-eight surface configurations are considered in detail. The book is liberally supplied with charts, tables and graphs. Appendices include sample problems.

FLUIDIZATION, Max Leva, McGraw-Hill Book Co., 336 pp. illustrated, $11.50.

A source book and reference work, the volume deals with the fluidized state, fixed beds and the onset of fluidization, dilute phase and moving solids, heat and mass transfer, and mixing. It gives a critical presentation of working correlations, explains fluidization phenomena, discusses spouting, and puts emphasis on foreign developments in this field.

EFFECTS OF HIGH-ENERGY, HIGH-INTENSITY ELECTROMAGNETIC RADIATION ON ORGANIC LIQUIDS, E. M. Kinderman, Stanford Research Institute, for Wright Air Development Center, U. S. Air Force. 55 pp.

Report of study undertaken to provide background information for the design of hydraulic fluids and lubricants for nuclear propelled aircraft. A series of organic esters, hydrocarbons, and miscellaneous compounds were subjected to radiation to determine the influence of their structure on stability.

1958 BOOK OF ASTM STANDARDS, American Society for Testing Materials, Philadelphia, Pa. First of 10 parts. 13,600 pp., $116 set.

The ASTM book this year increased from 7 to 10 parts. It contains 2450 standard specifications, methods of test, definitions of terms, and recommended practices. Part 2, Non-Ferrous Metals, is now off the press. Nine other parts include Methods of Test for: Metals, Paint, Naval Stores, Aromatic Hydrocarbons, Coal, Coke, Gaseous Fuels, Engine Antifreezes, Plastics, Electrical Insulation, Rubber, Carbon Black. These subsequent sections will be printed shortly.

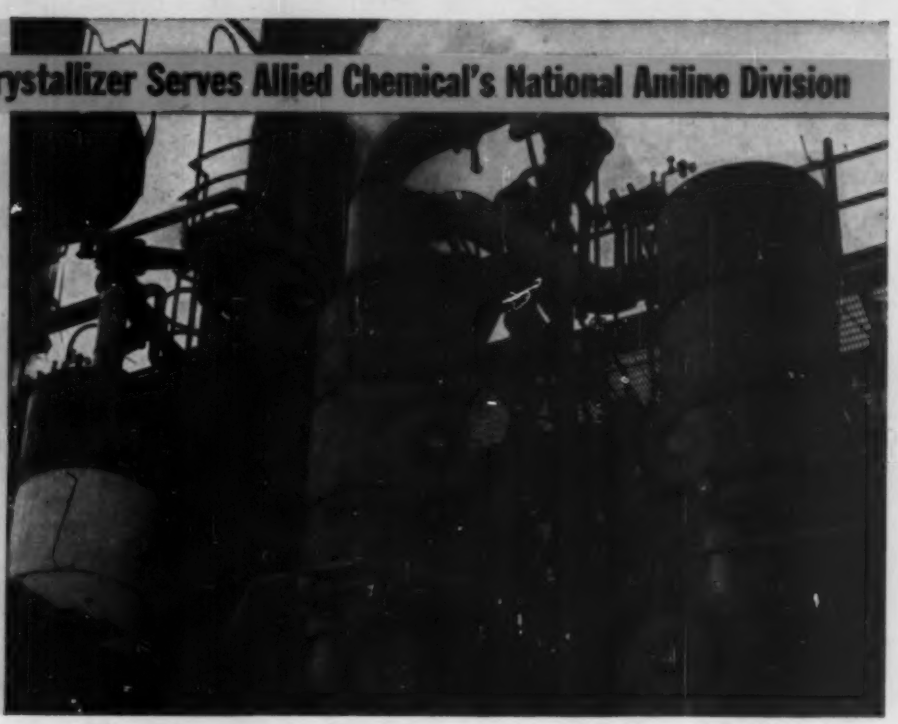
BIOCHEMICAL ENGINEERING, edited by R. Steel, (1958) Macmillan Co., New York, N. Y., 328 pp., $7.50.

A collection of papers, covering the principles and scope of biochemical engineering. Specific aspects are:

continued on page 24

Another CB&I Crystallizer Serves Allied Chemical's National Aniline Division

CB&I crystallizer system produces high purity, highly uniform adipic acid crystals for use in synthetic fibers at the Hopewell, Va. plant of National Aniline Division. Is one of several CB&I-built systems used by the company.



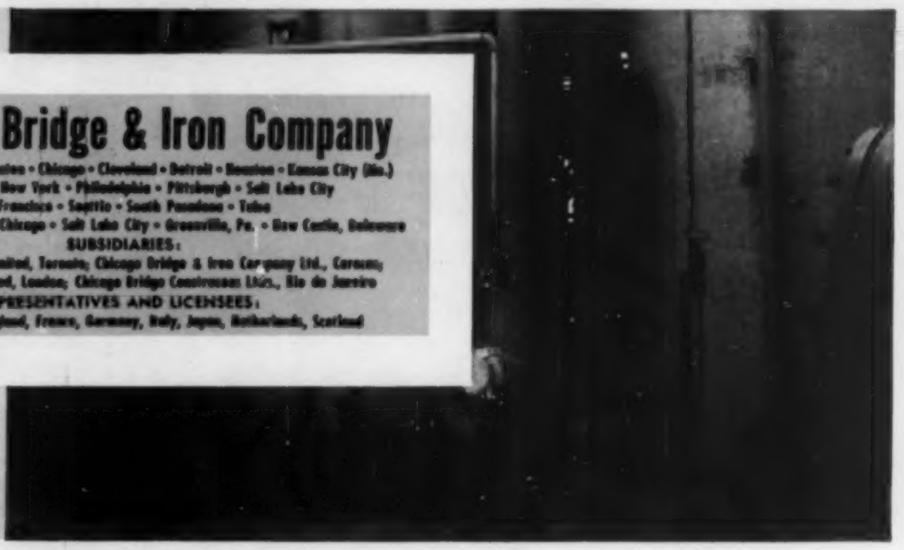
Three-stage system produces high purity adipic acid crystals

The chemical industry demands—and gets—uniform, high purity adipic acid crystals from the Allied Chemical's National Aniline Division plant at Hopewell, Virginia.

Here, a CB&I-built three-stage crystallization system *twice* re-dissolves the crystalline crop to remove impurities. Then the system's third effect produces the final *quality* crystals required as raw material for the chemical industry.

Fabricated of type 304L stainless steel to resist corrosion and to prevent iron contamination, the crystallizer system has been in continuous service for three years.

Dependable, profitable performance such as this is one reason so many CB&I crystallizer-evaporator customers—become repeat customers for CB&I processing vessels, which include: Crystallizers • Evaporators • Flash Evaporators • Condensers • Heat Transfer Equipment • Digesters • Vaporizers • Vacuum Dryers • Boiler Feed Water Equipment



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marginal notes

from page 22

micro-organisms and their activities, substrates for fermentation processes, sterilization of equipment, air and media; equipment design. Present trends and future development conclude the study.

Report of the Joint Program of Studies on the Decontamination of Radioactive Waters, U. S. Public Health Service and AEC, 62 pp., $1.00.

The results of studies carried on since 1950. Consideration is given to probable sources of radioactive contamination in the environment and to the potential health hazard of such contamination in drinking water. Sources: The nuclear bomb, atomic installations, Off-Commission users of radioisotopes. Findings (laboratory and pilot plant studies, and tests of emergency water treatment units), are discussed in relation to treatment processes involved.

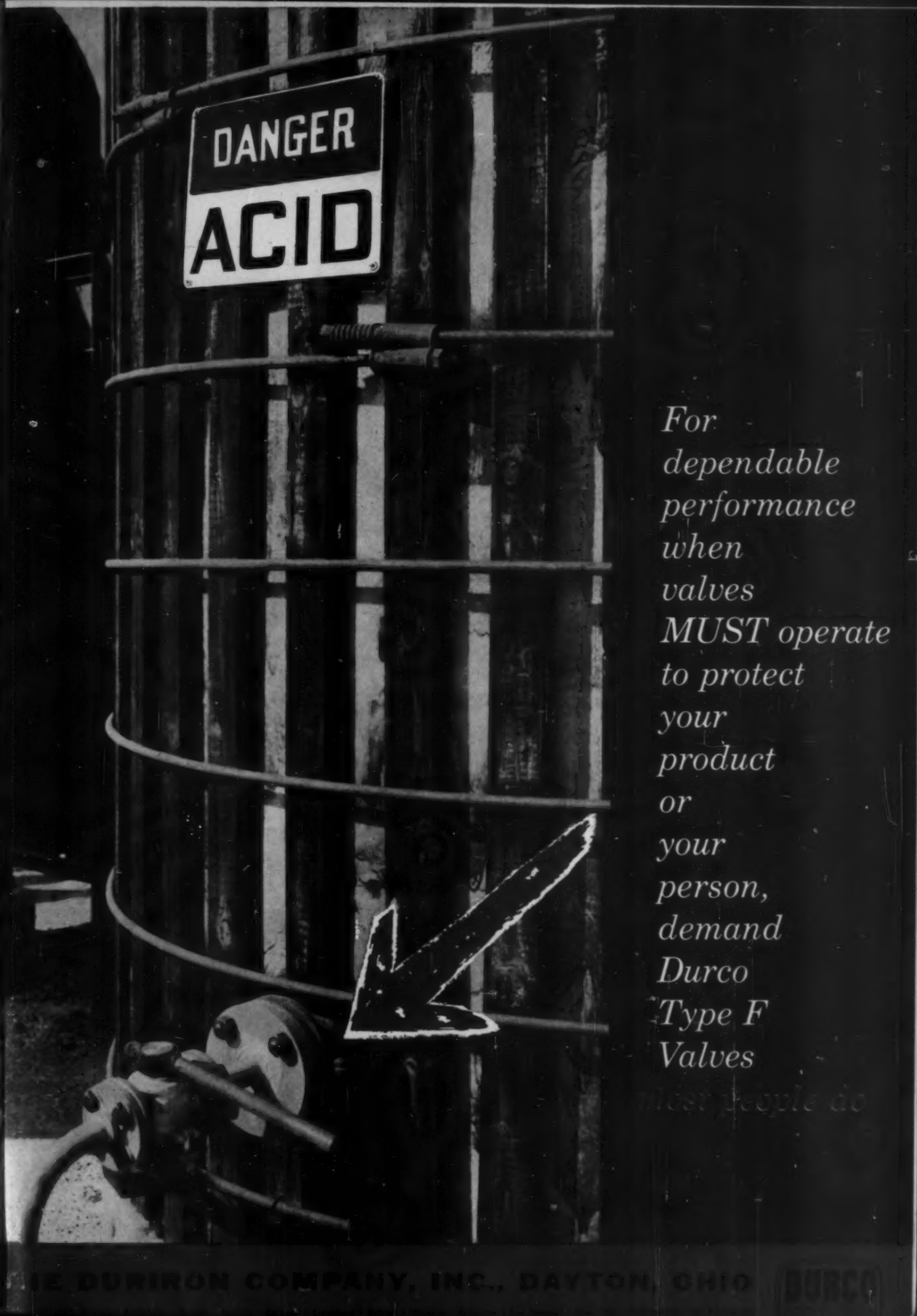
Handbook of Automation, Computation and Control, Volume 1: Control Fundamentals, edited by Eugene M. Grabbe et al., (1958), John Wiley & Sons, New York, N. Y., $17.00.

The first in a series of three volumes, this book provides information forming a foundation for the later volumes. It covers mathematics as applied to control, such as sets and relations, Boolean algebra, probability and statistics. This is followed by a compilation, and comparison of, various techniques of numerical analysis. Material on information theory, smoothing, filtering and data transmission, and feedback control theory is also included.

Sampled-Data Control Systems, John R. Ragazzini and Gene F. Franklin, (1958) McGraw-Hill Book Co., New York, N. Y., 331 pp., $9.50.

Presents analysis and design of sampled data feedback and control systems. Sampled data theory is developed, and serves as a base for the analysis and synthesis of linear digital systems, pulsed continuous systems, and their combinations in practice. In addition, the subject is broadly treated to include applications in communications, data processing, and filtering. A particular feature is the discussion on the use of digital computers as in-line controllers.

continued on page 30



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ACID
For dependable performance when valves MUST operate to protect your product or your person, demand Durco Type F Valves
most people do
THE DURIRON COMPANY, INC., DAYTON, OHIO
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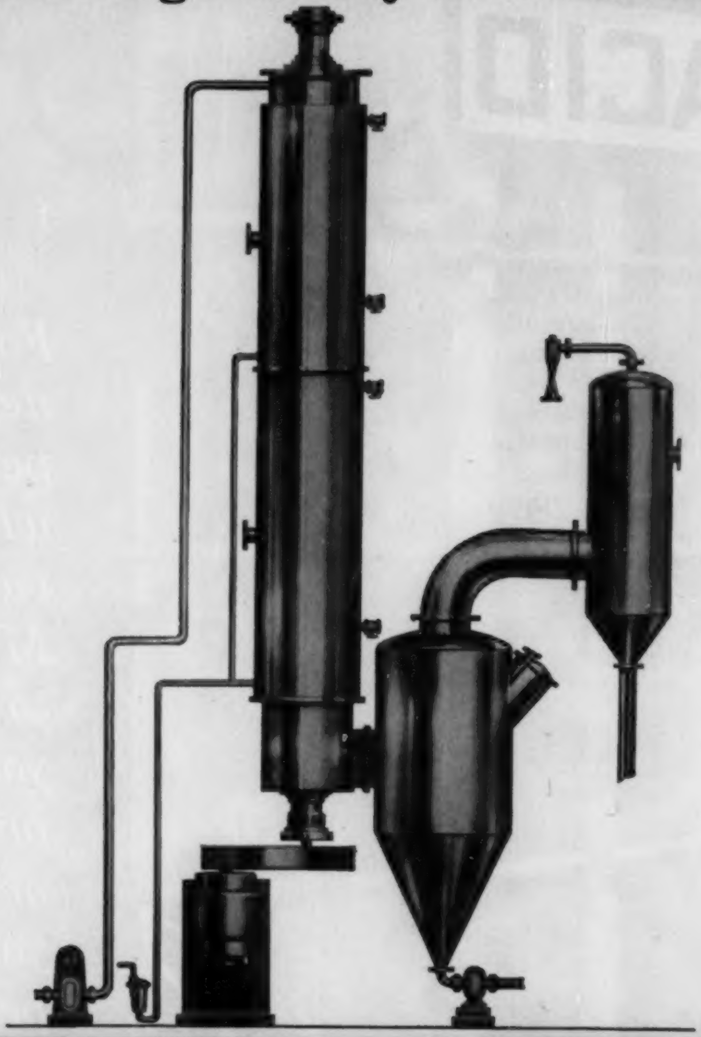
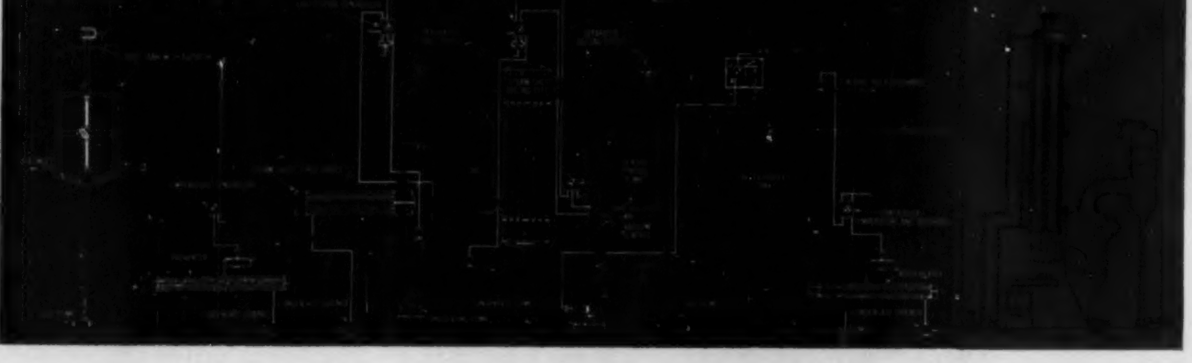
New Buflovak

...provides high density heat transfer...helps



ROTO-VAK on the line . . . shown here as a finisher used with Buflovak Double Effect Evaporator. This system is designed to produce tomato pulp concentrations to 40%-50% solids.



Agitated Film ROTO-VAK

upgrade product quality . . . cuts production costs

Whatever your product—viscous, foamy or extremely heat-sensitive—the new Buflovak Agitated Film ROTO-VAK will produce a high quality product . . . and build your processing profits.

A product of Buflovak's extensive background in evaporation, this ROTO-VAK permits *high density* concentration of a whole range of new materials. Turbulent, thin film action provides superior heat transfer rates with shortened controlled contact time.

Temperatures formerly regarded as critical for many heat-sensitive products are now practical. For more details of this new advance in profitable processing, write for the new ROTO-VAK Bulletin No. 383.

Handles any fluid material. Any material which can be pumped can be processed effectively in Buflovak's new ROTO-VAK.

External Vapor Separator provides high efficiency, centrifugal separation. Vapor and product are separated independently from the heating surface. True down-flow design eliminates reflux of product.

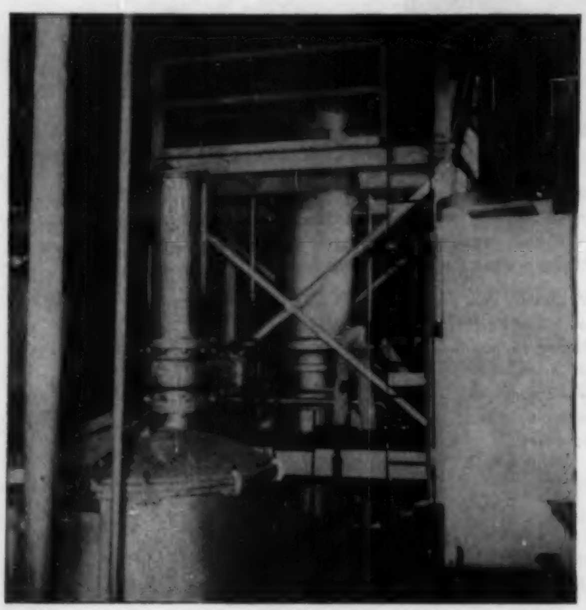
Main Drive at floor level affords easy access for maintenance. Located off the center of the rotor, the entire rotor assembly is easily removed when required.

External Bearings use well designed mechanical seals or stuffing boxes to eliminate product contamination. Only the rotor assembly contacts the product.

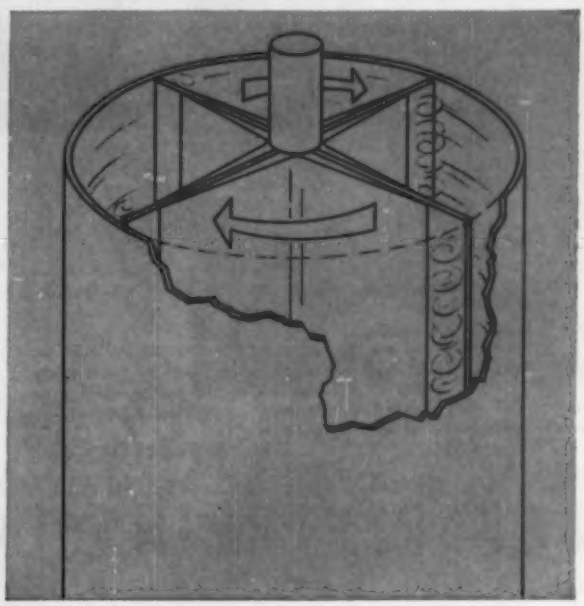
BLAW-KNOX

BLAW-KNOX COMPANY
Buflovak Equipment Division
1567 Fillmore Avenue, Buffalo 11, New York

ROTO-VAK produces tomato paste at 40% to 50% solids. The concentrated product retains its original qualities, is immediately ready for canning. An additional sterilization process is eliminated.



The spinning rotor agitates the down-flowing, thin-film of liquid into a violent turbulent action. Burn-on, and encrustation due to over-heating are eliminated.



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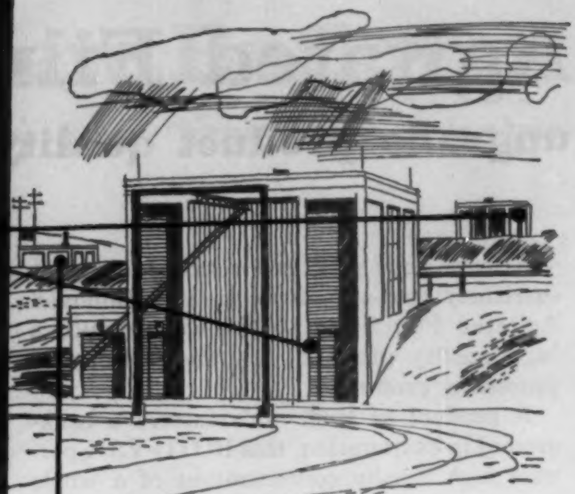
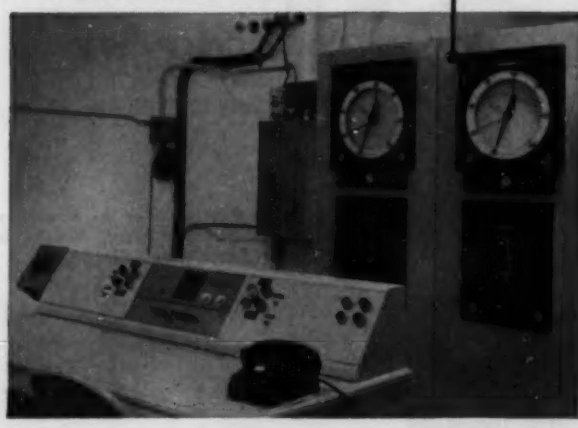


TWO MORE BAKER PERKINS MIXERS ON THE JOB at new *Thiokol*® solid propellant plant in Utah



Inorganic oxidizers, the chemicals which make solid rocket propellants burn with such intensity, are first ground to a particle size . . . blended thoroughly . . . then mixed with an elastomeric binder. Fundamentally, that's how Thiokol Chemical Corporation makes a fuel for a rocket motor. The mixing of high energy fuels is a delicate, exacting operation and the mixers must be highly efficient and absolutely dependable.

At the Brigham City, Utah plant, Thiokol has recently installed two more Size 18 JWRM-2 Baker Perkins mixers. Each of these mixers is constructed of stainless steel and has a 300 gallon working capacity. The units, housed in specially constructed buildings, are remote controlled from another building.

Because they are safe *and* efficient, more and more B-P mixers are being used by the rapidly expanding propellant industry. These same high standards of quality are also incorporated into the standard design mixers built for the chemical process industry.

Whatever your requirements may be, Baker Perkins builds mixing machinery to handle every job. Why not write today for Bulletin No. CE-58 containing information on B-P equipment for the chemical process industries.

BAKER PERKINS INC.

See our insert in Chemical Engineering Catalog.

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

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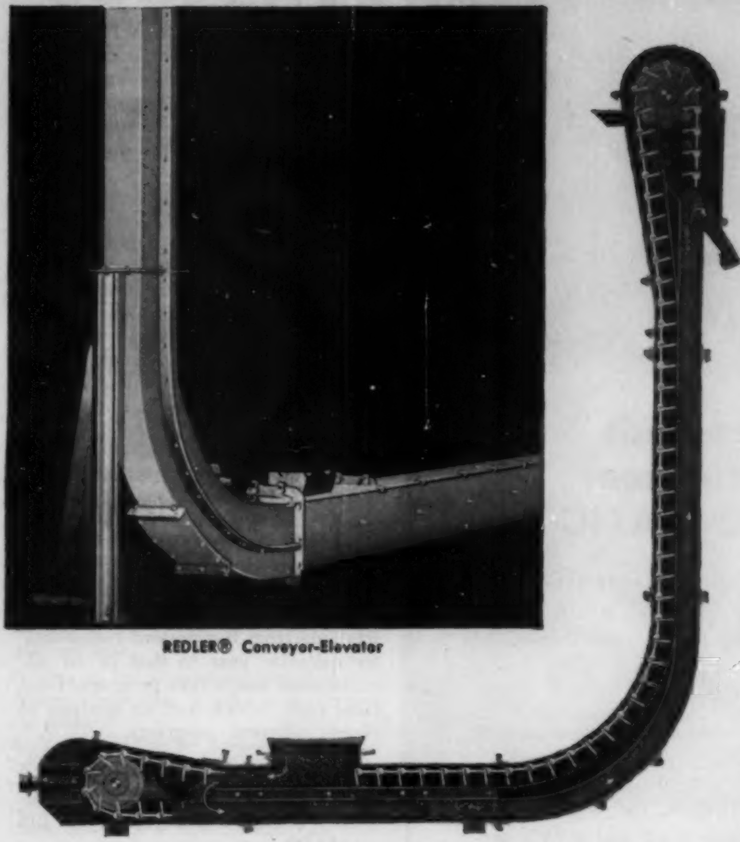
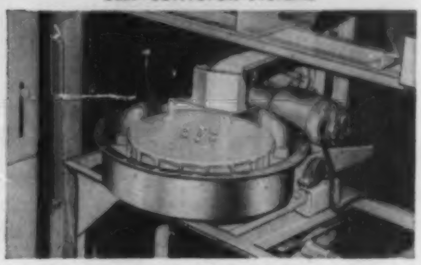
STEPHENS-ADAMSON



REDLER® Conveyor-Elevator

ZIPPER® BELT CONVEYOR-ELEVATORS

BELT CONVEYOR SYSTEMS



CONTINUOUS WEIGHER

SPEEDS EFFICIENCY...LOWERS COST IN CHEMICAL HANDLING

When you consult a conveyor manufacturer on a particular bulk materials handling problem, you do so because the consultant is a specialist in his phase of the business. But think of the advantages if that consultant were not only the manufacturer of a particular type of conveyor but a specialist in chemical handling systems.

STEPHENS-ADAMSON is just that kind of a consultant. The systems that S-A engineers are regularly designing and installing for the chemical processing industry are not based on a desire to sell a particular type of conveyor system — but the most efficient, profitable answer to the problem at hand. The reason is twofold — S-A's broad knowledge of the field and the fact that S-A makes not one, but several kinds of conveyor systems, some exclusive and patented by the company. Over 20,000 successful installations of the S-A Redler Conveyor-Elevator System alone, point up the breadth of S-A experience. Write today for full information.

MORE S-A EQUIPMENT FOR PROFITABLE CHEMICAL HANDLING

- Box Car Unloaders
- SWIVELOADER® Centrifugal Thrower Unit
- TELLEVEL® Bin Level Controls
- Bucket Elevators
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S-A

MATERIALS HANDLING PRODUCTS

SEALMASTER BALL BEARING UNITS

ENGINEERING DIVISION

STEPHENS-ADAMSON MFG. CO.

GENERAL OFFICE & MAIN PLANT, 57 RIDGEWAY AVENUE, AURORA, ILLINOIS

PLANTS LOCATED IN: LOS ANGELES, CALIFORNIA • CLARKSDALE, MISSISSIPPI BELLEVILLE, ONTARIO

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marginal notes

from page 24

Operational Research in Practice, edited by Max Davies and Michel Verhulst. (1958) Pergamon Press, New York, N. Y., 201 pp., $12.00. Published for the Advisory Group for Aeronautical Research and Development.

A report of a NATO conference on the subject. Discusses how various operations research techniques have been applied to specific problems such as methods of air defense, systems of evaluation and military planning, logistic and transport operations, and war games. A considerable amount of the material included has application to civilian and industrial goals.

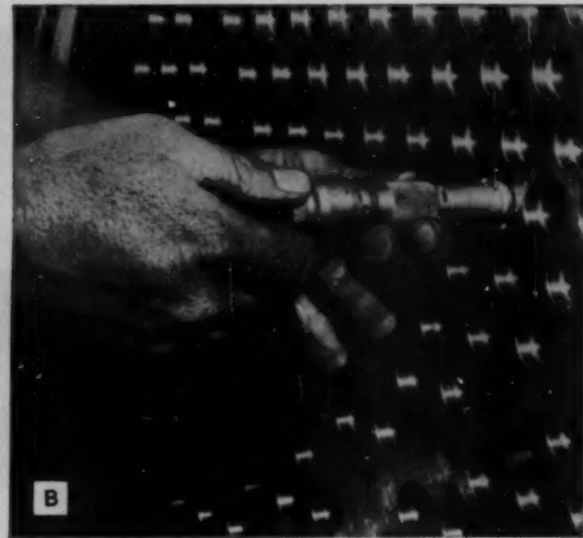
Year-Around Operation of Colleges, Engineering Research Bulletin No. 41, Elmer C. Easton, Dean, College of Engineering, Rutgers University, 50¢.

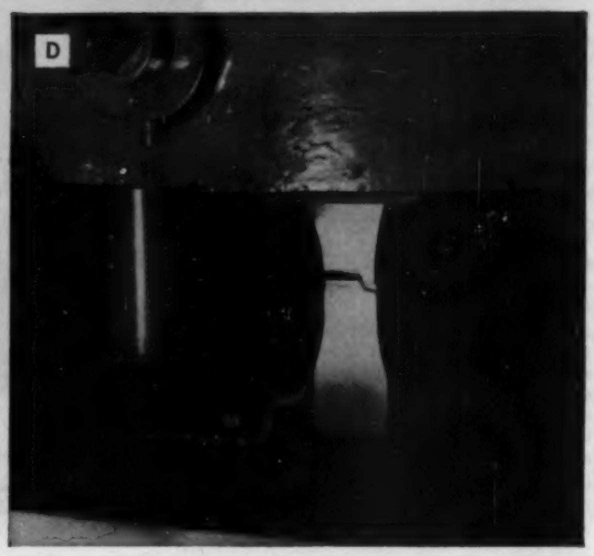
A study of the advantages and disadvantages of changing the academic schedule from the present two-semester calendar year to that of an all-year-round instruction program. Contains eight tables, and an analysis of eleven different programs.

An Introduction to Fluid Dynamics, G. Temple, (1958), Oxford University Press, New York, N. Y., 195 pp. $4.00.

Stresses the fundamental dynamical principles and their immediate applications to the types of fluid flow observed, particularly the disturbance flow created by the motion of a solid body through fluid. A description is given of the theory of irrotational motion, and of velocity potential, and full use is made of functions of a complex variable in problems of plane parallel flow. A number of simple fields of flow are studied to indicate the solutions of the fundamental equations and illustrate general hydrodynamic theorems.

Selected Reading for Young Engineers, issued by the Engineers Council for Professional Development, is part of "First Five Years" cultural development program for young graduate engineers. The 8-page pamphlet includes suggestions in the field of biography, travel, history, economics, sociology, natural sciences and general literature. Each book on the reading list has either been reviewed by the Committee or recommended by prominent educators.





Our testing team works for you

Your requirements come first with our testing team. Working directly under our chief engineer, they check and double-check the fabrication work of our production crews. Your own men couldn't do a more faithful job. Come and see for yourself. Or write for Bulletins HE and CI.

A For a close fit—Incoming tubes are always miked for exact size. Matching tube sheets are then reamed for a close fit that contributes to heat exchanger quality.

C In the dark—but not for long. Our own darkroom permits immediate developing of X-ray films... gives our inspector a fast check of weld structure and soundness.

B Tailored to size—Quality dictates precise tube hole diameter. Constant micrometer checking tells our inspector that tube sheets are exactly right to meet your specs.

D Reply requested—Our inspectors get many prompt reports from our own testing lab. Here's a tensile test on our own machine. It helps speed testing and inspection.

Downingtown Iron Works, Inc.

106 Wallace Ave., Downingtown, Pennsylvania

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APRIL 1959

trends

What the CPI's record shows... and predicts

Gleanings from the Annual Reports—Here is a *technical* analysis of the more significant facts contained in the annual reports of 30 CPI firms. . . .

Big Capital Spenders for 1959—High on the honor roll is *Texaco,* with an avowed $429 million tagged for capital expenditures. *Sun Oil* is next, with $90 million to partially cover a major expansion program, some in combination with others. *Kennecott Copper* will also spend $90 million, but much of this is for smelter facilities. *National Distillers* is pegged for $20 million, plus what *may* be appropriated for further expansion of polyethylene facilities at Houston. *Texas Gulf Sulfur* has $6.0 million budgeted, chiefly for completion of a sour gas recovery plant in Canada with annual capacity of 100,000 tons. *Metal & Thermit* has $1.2 million in mind. *Diamond Alkali*—modernizing Painsville among other projects —$6.8 million. *Atlas Powder* plans to continue at the rate of $5.5 million. Without an announced price tag, *DuPont* is constructing facilities for "Delrin" acetal resin, and "Teflon" FEP fluorocarbon resin which can be processed in standard equipment.

R&D Tally—*DuPont* again heads CEP's list, spending $90 million exclusive of lab construction. A new family of lightfast red pigments, elastic "Fiber K," photopolymer printing plates, a new odorless household bleach, fibrous potassium titanate insulation, a new synthetic fluorocarbon rubber, polyvinyl fluoride film which weathers without degradation, octafluorocyclobutane inert gas, and a series of fluoroalchohol intermediates, are among the new products announced as under active development. *Union Carbide Chemicals* spent $71 million; completed were plastics labs in New Jersey and a chemicals technology center in West Virginia. *Monsanto's* R&D tab for 1958 was $23.4 million, of which 24% went for new products, 34% exploratory, and 42% product improvement projects.
Merck's R&D outlay was $17 million, or 8% of gross sales. *Allied Chemical* racked a nice score of $16 million. Completed during the year was an extensive UF_6 pilot plant program. *Minnesota Mining* reports that 25% of its sales for 1958 came from products developed during the past 5 years is currently spending $16.5 million for R&D—4% of sales. *Koppers* again spent $7 million on R&D of which 25% was for exploratory projects (in contrast to 6% in 1956.) *Union Oil* spent $6.5 million, or 1.6% of sales. A 200 ton/day tar sands pilot plant is in operation at Orcutt, Calif., and an underground combustion experiment at Santa Cruz, Calif. *Celanese* reports $5.7 million. *Diamond Alkali* $3.6 or 3.2% of sales with major expansion of licensing arrangements. *Atlas* reported $3.3, opening a new Research Center. *American Potash* continues to look into boron, alkali metals including Li, Ru, Ce, and Mn and its compounds. Over 50% of new product R&D was in boron chemistry. Expenditures were 4.1% of sales.
Commercial Solvents reports its major R&D goal is to extend and expand the company's present business. *National Distillers* obtained 45 new patents, and the R&D program emphasis is on plastics, Na-based chemicals, and special metals.
Metal & Thermit is entering into joint R&D projects with large chemical companies on organometallic intermediates. *Fluor* is studying treatment of natural gas containing CO_2, a ruthenium adsorber bio-oxidation of waste waters, and considering radical changes in cooling tower packing and design. *Goodrich* occupied a new R&D building devoted to ceramics and metallurgy. *Sun Oil* was granted 93 new patents, bringing its unexpired total of 643. *Wyandotte* is searching for new products based on alkylene oxides. *Allied* is continuing nitrogen tetroxide studies, has been revaluating R&D projects resulting in some transfer of activities.

On the Production Front—*Texas Gulf Sulfur* reports total U.S. production at 6.8 million long tons in 1958, compared to 7.0 in 1957. Their shipments of Frasch S were off 8%. . . . *Merck* began production of silicon and monosodium glutamate, discontinued formaldehyde and hexamine. . . . *Pfaudler-Permutit* is hopeful that low in sales curve was reached in last half of '58. . . . *Allied* is completing liquid fluorine facilities, caprolactam process improvements are credited with a doubling of plant capacity. . . . *Freeport Sulfur* reports increased export tonnage sales of S; mining off the Louisiana Coast is expected to begin in 1960. . . . *Pittsburgh Coke* completed a 50% expansion of plasticizer capacity and a new fumaric plant. Its activated carbon facility is to undergo further expansion. . . *Celanese* reports progress with trimethylolpropane and acrylate esters which came into production early in '58. . . *Monsanto* introduced a new fertilizer, three plasticizers, 47 plastics, plus other items. . . . *Sun Oil* installed a 12.5 ton/day S recovery unit at its Toledo refinery.

opinion and comment

Return to Secrecy?

Next month a panel will analyze what may be one of the most serious problems confronting the chemical process industries and our profession. This is the trend towards secrecy. The panel will be the symposium on International Licensing and Collaboration, on Monday morning, May 18, at the Kansas City National A.I.Ch.E. meeting.

The trend towards secrecy has roots that are both varied and deep. One has to do with our patent system, which is under attack from many directions. The O'Mahoney Committee hearings have focused attention on serious proposals to weaken or abandon the system. On the other hand the anti-trust activities of the present and previous administrations have increasingly employed compulsory licensing of patents as a means for accomplishing desired results. Both of these factors—hearings and compulsory licensing orders—have brought concern to the minds of those who have responsibility for the huge R&D expenditures which are expected to produce licensable patents. Compulsory licensing is thought by many to make patents merely "hunting licenses" for those who would enjoy the information benefits at least cost.

Another root lies in the international scene, with both the European Economic Community and the cold war with the Soviet Bloc in the picture. Through the regulatory activities of our Department of Commerce, all exports from the U. S.—including technical data—are under its control. Its policies have been to permit unencumbered export of the latter to friendly countries for their own use, but to be stringent about anything that would go behind the iron curtain. A member of the Department staff will be on the panel to explain latest policies on this and other matters.

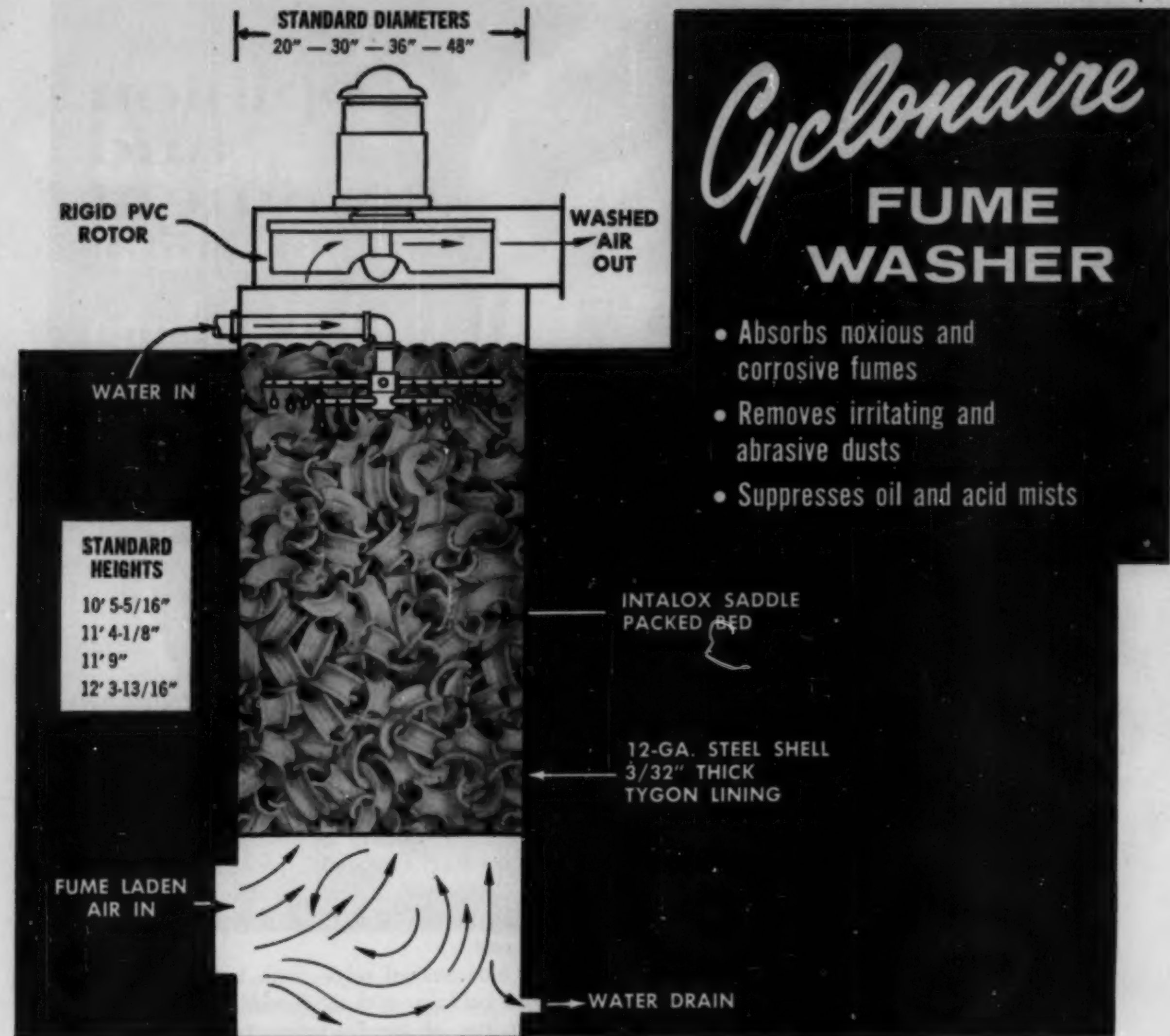
The European Economic Community is said to be moving towards compulsory licensing for its member-States, but without anti-trust in the background. The effect will therefore be to bring the technological resources of the various countries into a common marketing front—which is expected to offer serious (united) competition against individual (trust hazard sensitive) U. S. firms.

As one panelist described the situation, it is one which can very well result in the process industries' return to the ancient system of protecting information by secrecy—with fences instead of patents.

Would this be good for the nation—or for that matter the profession? The answer to this should be an obvious "no."

Here then is a complex, dangerous situation, that should be resolved only by taking into account the *technological* factors and consequences. Its high time, in other words, to keep an eye on the lawyers and lawmakers.

For those who cannot attend the panel presentations and discussions, CEP will do its best to report fully on the situation. J.B.M.



The "Cyclonaire" is a surprisingly compact wet bed scrubber. It will fit almost anywhere, but it does a fume removal job formerly possible only with expensive custom-designed units. Removal of many gases (of 1% concentration or less) is up to 99% effective. Low power requirements make it very economical to operate.

The standard "Cyclonaire" consists of a bottom section containing a packing support plate, fume intake duct, and liquid drain; two intermediate sections packed with Intalox Saddle Packing; a distributor section containing a water or liquid inlet and liquid distributor; and a top section containing the blower, drive motor and washed air outlet.

The unit is made of 12 gauge steel, lined with 3/32" thick Tygon sheet plastic. The rotor is made of rigid PVC plastic. All exterior surfaces are protected with Tygon "ATD" Hot Spray Paint.

The "Cyclonaire" is available in four sizes with rated capacities of 750, 1650, 3500 and 6000 cfm.

Its low initial cost, its low operating cost, its high efficiency make the "Cyclonaire" a logical choice for a wide range of fume scrubbing operations. Full technical data in Bulletin FW-10. Write for it today.

OUR 100th YEAR

PROCESS EQUIPMENT DIVISION

U. S. STONEWARE

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376F

For more information, turn to Data Service card, circle No. 28

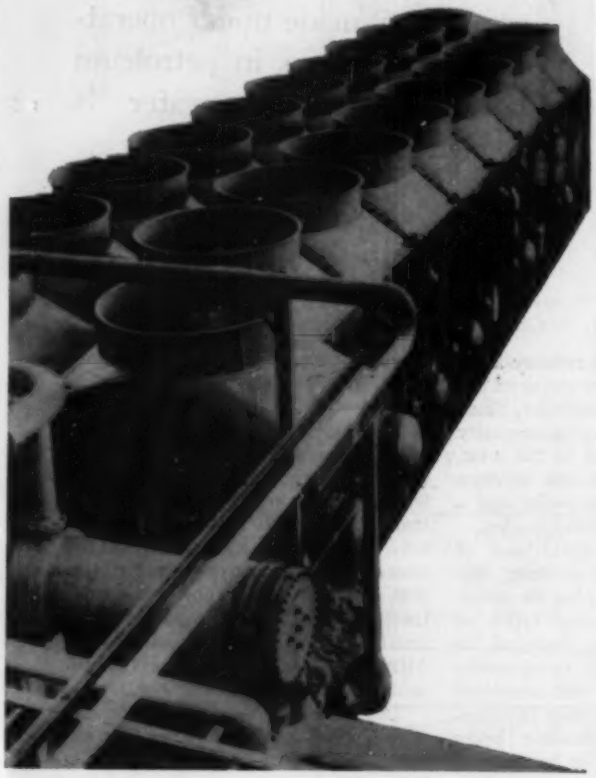
Air cooled heat exchange

Air Fin Coolers are now being specified for almost the complete range of refinery oil product cooling and condensing services. At the same time, the chemical industry is expected to offer considerable application inasmuch as it uses 24 percent of all industrial water, 82 percent of this for cooling.

Economics generally favor direct air cooling to within 40°F of design dry bulb temperature, but narrower differentials may be accommodated, sometimes with the addition of combination shell and tube coolers with cooling towers.

There is a need for a two step program: To develop a better design basis and rating procedure through experience with continuous operation, and to apply this knowledge towards a greater degree of standardization of equipment.

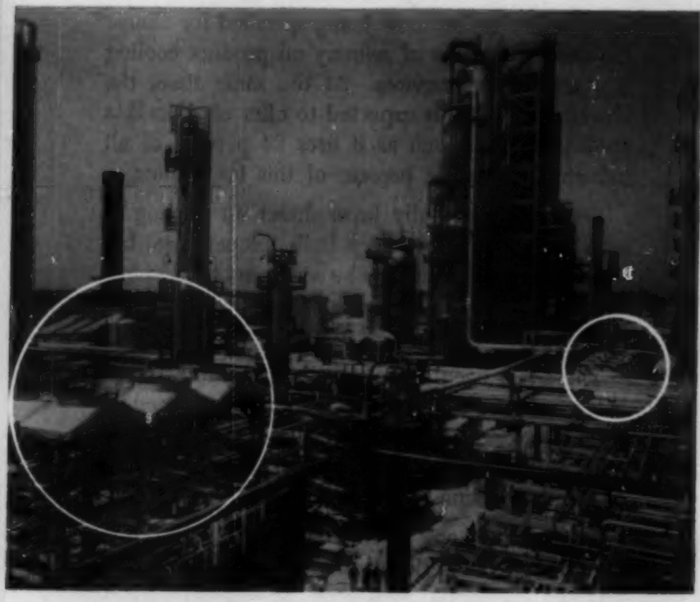
The editors hope to stimulate application interest through this series of articles, which are based on two symposia presented at the Cincinnati Annual A.I.Ch.E. Meeting, December, 1958. William W. Akers deserves recognition for having organized these high-interest symposia, and for aiding with the following articles.—Editor.



Part 1 . . . This issue

Parts to come . . . Future issues

Thermal surface fouling . . . Air cooling in chemical plants . . . Field performance testing of air-cooling equipment . . . Optimum trim cooler temperature . . . Economics and applications of air coolers.



Typical air cooled installations (in circles) at Standard of Ohio's Toledo refinery where some of the cost comparisons were made.

Air vs. water cooling *cost comparisons*

Actual case histories of comparisons made under operating conditions in petroleum refineries where water is plentiful.

John W. Thomas
Standard Oil Co. (Ohio)

AIR-COOLED EXCHANGE HEAT

At Sohio's Lima, Ohio refinery a revamp of the Cat Cracker required the addition of one large condenser. Since the existing cooling tower capacity was already being taxed to the limit, it was necessary to choose between the installation of an air-cooler and a conventional shell-and-tube cooler.

When comparing capital cost of alternate methods of cooling, one must consider material plus the installation costs for: different types of coolers, process piping, electrical facilities supplying power to air-cooler fans, and cooling tower with attendant piping and water treatment facilities. In the particular application being used as an example, the fractionator overhead condenser had the following process specifications:

Duty—33,000,000 Btu/hr
Temperature (in)—250°F
Temperature (out)—120°F

For the air cooler, a "trim cooler" was selected to cool the overhead stream from 140°F to 120°F. The total estimated cost for conventional water cooling equipment was $140,000, the shell and tube equipment itself costing 32% of the total. Estimated cost for air cooling was $108,000, the air cooler cost representing about 67% of the total.

The operating costs for the conventional water cooling system was es-

continued on page 40

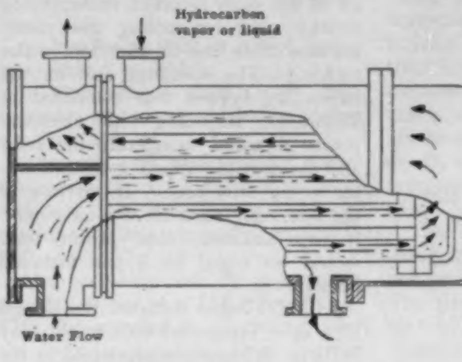


Figure 1. Conventional cooler and condenser.

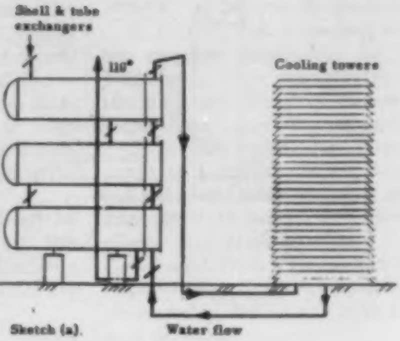


Figure 2. Conventional water cooling.

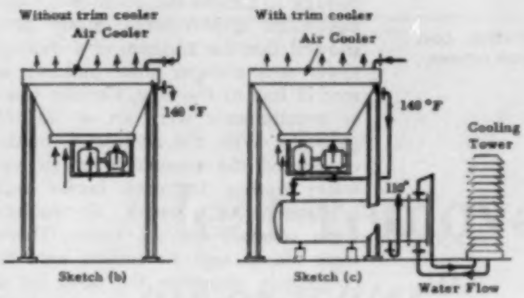


Figure 3. Air cooling systems.

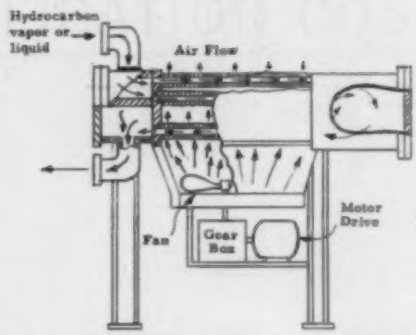
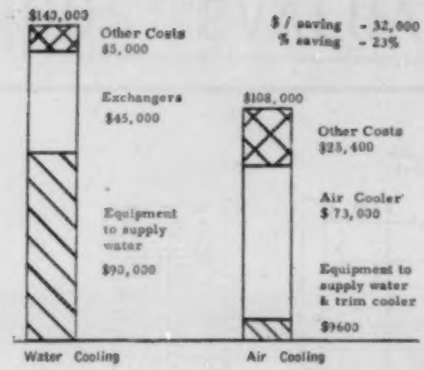


Figure 4. Air cooler (uses air as coolant).

PROCESS SECTIONS	EXCHANGER	TOTAL DUTY BTU/HR.	AIR COOLER TEMP. IN °F	AIR COOLER TEMP. OUT °F	TRIM COOLER TEMP. IN °F	TRIM COOLER TEMP. OUT °F	WATER SAVING (gpm)
Crude-Vacuum Unit	Crude Tower Top Reflux Cooler (C105)	16,000,000	233	200	None	None	1467
	Heavy Naptha C Cooler (C109)	3,950,000	305	140	140	95	
	Kerosene Cooler (C110)	7,850,000	375	140	140	95	751
	Light G.O. Product Cooler (C111)	5,050,000	490	140	140	110	
	Vacuum Twr. Bottom Flux Cooler (C112)	4,100,000	680	450	None	None	234
Cat Cracker	Fractionator O/H Cond. (C301)	71,500,000	290	140	140	120	4025
	Gasoline Splitter O/H Cond. (C316)	30,740,000	225	130	None	None	1710
	Decanted Oil Product Cooler (C323)	7,980,000	675	200	None	None	454
Hydrogenation Unit	Lean Oil Cooler (C426)	7,510,000	317	140	140	100	419
Reformer	Reformate Splitter O/H Cond. (C509)	15,410,000	230	150	None	None	838
	HV Reformate Product Cooler (C512)	14,500,000	320	140	140	120	386

Figure 5. Comparison of water saving for air cooling of eleven refinery services.



Cost comparisons

Figure 6. Capital cost comparison at one refinery.

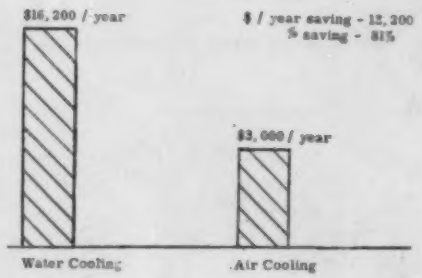


Figure 7. Operating cost comparison at one refinery.

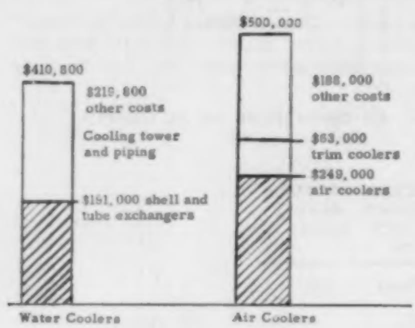


Figure 8. Capital cost comparison for eleven refineries.

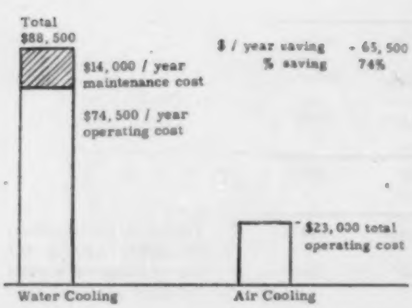


Figure 9. Operating cost comparison for eleven refineries.

Air vs. water

continued from page 38

timated to be $16,200/yr, including all of the costs involved in supplying treated water for cooling, plus maintenance costs due to attendent water corrosion. The operating cost for the air-cooling system was estimated at $3,000/yr, including the electrical power required to operate the fans, and the cost of supplying treated water to the *trim cooler*. In arriving at the operating costs for the air cooler, it was assumed, that power *used* would be equal to ⅜ the installed horsepower.

In 1956 Sohio initiated the design of a new, integrated 60,000 bbl./day refinery. Processes incorporated in the new plant included: a Crude and Vacuum Unit, a Delayed Coker, a Cat Cracker, a hydrogenation unit, a Cat Reformer, Cat Poly Plant, and treating plants. In the preliminary studies, it was apparent that the existing water line to the lake was not large enough to handle the additional cooling water requirements. Study also showed that the addition of a cooling tower was cheaper than building a second line to the lake. Cooling tower requirements were set at 30,000 gal./min. With the contractor, Sohio considered the economics of air vs. water cooling for each cooler and condenser. As a result, air coolers were selected for 11 units. There were not enough air coolers used to completely eliminate the need for a new cooling tower; however, there were enough to reduce the cooling tower size. If the circumstances are such that the installation of air coolers will eliminate the need for adding a cooling tower, a capital cost comparison will be weighted very much in favor of the air cooler.

The basis for the economic comparison of air-cooling vs. water-cooling was as follows:

a. Ambient air temperature used in design of air coolers was 95°F.

b. Capital cost for *shell-and-tube* units was based on use of 13-gauge carbon-steel tubes.

c. Capital cost of trim coolers was based on admiralty tubes if lake water was the coolant, and carbon-steel if cooling-tower water was the coolant.

d. Gear box drive was to be used with air-coolers, and cover-plate header design was required, if fouling or corrosion was expected in the particular service.

e. Platforms were required around all air-coolers, to provide access to

both tube-ends, motors, and gear boxes. These were considered necessary because air coolers are located high above pipe alleys.

f. 10-gauge tubes were used in air coolers wherever corrosion appeared likely.

g. Maximum size air-cooler motor was limited to 20-hp.

h. Maintenance costs (other than corrosion *attendent* with water) were not included.

The total estimated cost for water-cooling facilities for the eleven services was $410,000. The cost for air-cooling facilities amounted to $500,000.

The operating costs for water-cooling was estimated at $88,500 per year. This figure included *all cooling*, plus the costs for supplying treated water for maintenance due to attendent water corrosion. The operating costs for the air coolers was calculated to be $23,000/yr., assuming that cost of electric power to operate the fans is based on 50% use of the installed horsepower. The operating costs also include all costs required to supply treated water to the trim coolers, and maintenance costs due to water corrosion in the *trim* coolers. These costs are based on the *same* average cost/sq. ft. used for calculation of water-corrosion cost for the shell-and-tube case.

The operating savings realized by using air-cooling amounts to $65,500 per yr. This represents a 74% saving. The payout of additional capital for air-cooling is:

$90,000/65,500 = 1.4 yr.

Some advantages of air-cooling not included in the cost comparison are:

1. With air-cooling, the loss of operating dollars resulting from water fouling is eliminated. This can be a large saving when the units are operating at, and above design capacity.

2. Fouling due to cooling with water requires scheduling for bundle cleaning at least yearly. The cost of cleaning and the cost of associated "unit down time" is appreciable.

3. In the particular comparison made for Toledo's facilities, Sohio considered water corrosion costs equal to *average* costs experienced in Sohio's plants with *brass* bundles.

Condensed from "Economics of Air Cooling in Refinery Installations," presented at A.I.Ch.E. Cincinnati Annual Meeting.

APPLICATION COSTS

Heat removal
air or water?

Bob G. Perkins
Celanese Corp. of America, Pampa, Texas

AIR-COOLED HEAT EXCHANGE

In any given location, water from a cooling tower will be available at a temperature somewhat lower than ambient air temperature during the summer months. In a hot, humid climate, such as that found near the Gulf Coast, a 90°F dry-bulb temperature and 70% humidity are common. Assuming a minimum approach of 5°F to wet bulb on the cooling tower, the cooling water temperature will be only 3°F lower than the ambient air temperature. In hot, arid areas, such as Arizona, cooling water may be available as much as 25°F lower than ambient air temperature. This would be true for example with 105°F ambient air, a 25% relative humidity, and a 5°F approach. It is obvious that high condensing temperatures are more favorable for air.

Under installation or capital costs, a number of items must be considered for each route. For water, the costs of cooling tower and basin, makeup water facilities, treatment equipment, cooling water circulating pumps and

continued on page 42

Heat removal

continued

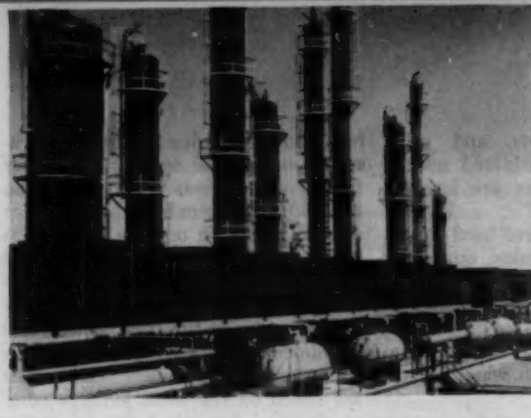
drivers, power supply, necessary supply and return piping, blowdown facilities, and shell and tube exchangers contribute to this figure. For the air-cooled unit, the costs of fans, drivers, gear boxes, structure, power supply, and exchanger bundles comprise the installed cost.

Installation costs for the air-cooled exchanger in a given condensing service will not necessarily be higher than a shell and tube, plus a pro-rata share of the cooling water facilities. If condensing temperatures are high, the installed costs for cooling water units will usually be greater than for air units. A given air cooled unit may handle twice the heat load with a high condensing temperature than it will with a low condensing temperature. The same is true for a given shell and tube exchanger except that the cooling water demand would be doubled, making the total cost higher. On the other hand, a low condensing temperature increases the surface area of both the shell and tube, and the air unit. Since the prorata share of the cost of cooling water is a function of heat load, the overall cost for the shell and tube installation will be relatively low. The cost of the air cooled unit auxiliaries, structure, foundations, fans and drivers will increase proportionately with the surface area, making the total cost higher than the cooling water unit.

Some of the more common problems which arise in water treating are: excessive scaling in exchangers; corrosion of the exposed metal surfaces in the cooling water system; algae and bacterial growth; deposition of dirt, silt, and mud in exchangers; and exchanger leakage contaminating process materials with cooling water or vice versa. Unfortunately, the severity of these problems cannot always be predicted for a new system, particularly at a new plant location.

For water, the power requirements usually can be broken down into three parts: makeup water, circulating demands, and cooling tower fans. For the air unit, the power required is that to drive the fans. Considering the Celanese Chemical Plant at Pampa, Texas, for example, the overall breakdown is roughly as shown in table A on page 43.

Quite frequently the space occupied by shell and tube exchangers is ade-



A view of several induced draft air-cooled condensers handling vapors from distillation towers. The units are installed on the pumphouse roof above process lines connecting the towers thus saving valuable space as well as money on large stainless steel vapor lines.

Quantity = 100,000 Lb./Hr.
Heat Duty = 17,500,000 Btu/Hr.
Condensing Temp. = 244°F

	Air	Water
U, based on inside area, Btu/Hr. (Sq. Ft.) (°F)	90	138
LMTD, °F	112	148
Area Required (inside) Sq. Ft.	1,730	850
Capital Investment		
Cooling Tower (pro-rata share—1,750 gal./min. from 10,000 gal./min. tower at $200,000 complete)		$35,000
Exchangers (stainless steel installed complete)	$43,200	$12,700
Total Capital Investment	$43,200	$47,700
Operating Costs (annual)		
Cooling Water Makeup and Treatment at $0.005/1,000 gal. cooling water circulated		$4,600
Power at $0.006/Kwh	$2,400	$3,700
Depreciation 7% on Exchangers		$900
5% on Cooling Towers	$3,000	$1,700
Maintenance (1% on Air, 3% on Water)	$400	$1,400
Total Operating Cost/Yr.	$5,800	$12,300
Return on Investment 10% after Federal Tax at 50%	$8,600	$9,500
Total, Operating Cost and Profit	$14,400	$21,800

Table 1. Evaluation of air vs. water as cooling medium for condensing acetic acid at atmospheric pressure.

Quantity = 51,800 Lb./Hr.
Heat Duty = 15,300,000 Btu/Hr.
Condensing Temp. = 160°F

	Air	Water
U, Btu./hr. (°F) (Sq. Ft.) inside area	105	150
LMTD, °F	43	64
Area Required (inside), Sq. Ft.	3,400	1,600
Capital Investment		
Cooling Tower (pro-rata share—1,530 gal./min. tower at $200,000 complete)		$30,600
Exchangers (stainless steel installed complete)	$85,200	$22,600
Total Capital Investment	$85,200	$53,200
Operating Costs (annual)		
Cooling Water Makeup and Treatment at $0.005/1,000 gal. cooling water circulated		$4,000
Power at $0.006/Kwh	$4,700	$3,200
Depreciation 7% on Exchangers	6,000	1,600
5% on Cooling Tower		1,500
Maintenance (1% on Air, 3% on Water)	900	1,600
Total Operating Cost Per Year	$11,600	$11,900
Return on Investment 10% after Federal Tax at 50%	17,000	10,100
Total, Operating Cost and Profit	$28,600	$22,000

Table 2. Evaluation of air vs. water as cooling medium for condensing low boilers at atmospheric pressures.

quately supplied by normal spacing of fractionating towers and allied equipment. Air cooled exchangers require considerably more space. However, by installing them above pipeways with the exchanger supports as part of the pipeway supports, any space problems can be diminished if not eliminated. This may be desirable to reduce process piping costs, particularly where stainless steel overhead vapor lines are required, even where the space occupied by the air-cooled units is not critical. The location of a cooling tower and allied equipment may not be so easily solved. To minimize piping, a tower located near the fractionating towers is desirable. However, fogging and misting can create poor working conditions nearby, particularly in winter months. Location outside the operating area can also be a problem if public roads or private property are located nearby.

Repairs on drivers (electric or turbine), gear boxes and fans for the air-cooled exchangers are quite low for

continued on page 44

Table A

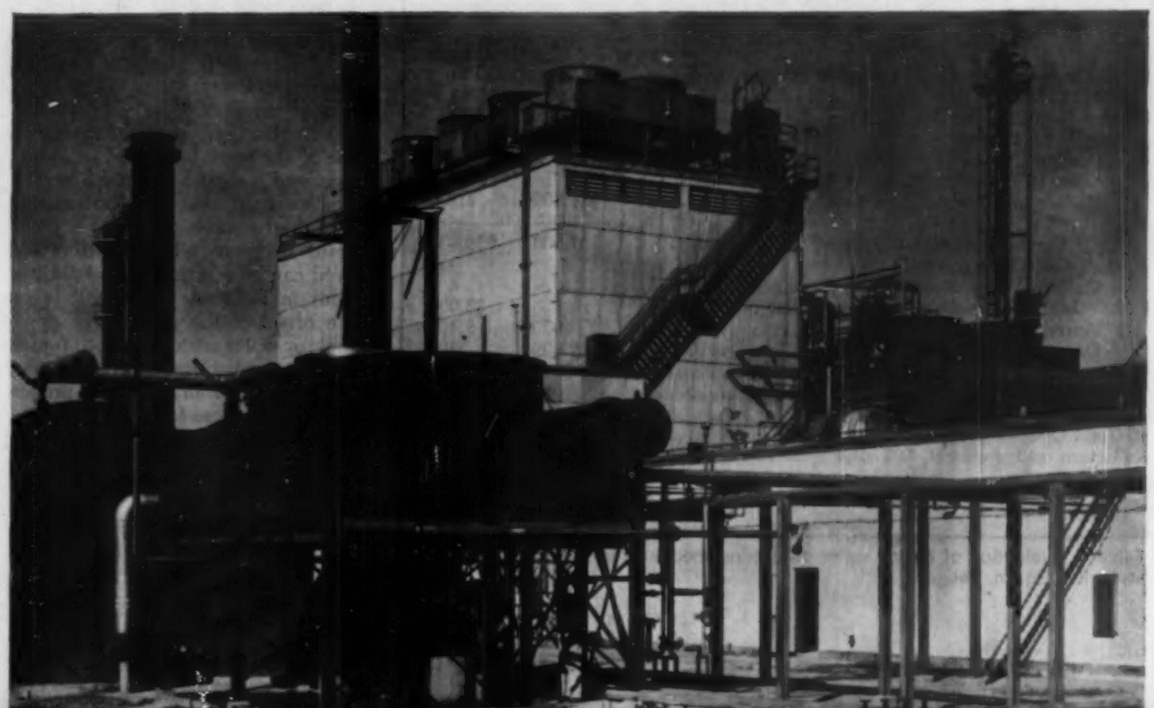
	Cooling Water System	Air Cooled Systems (Condensing and Sub-Cooling)
Heat Duty	350 Million Btu/Hr.	613 Million Btu/Hr.
Hp for Makeup H_2O	200	
Hp for Fans	800	2640
Hp for Circulation	800	
Total Hp Requirement	1800	2640
Hp/Million btu	5.1 design	4.3 design

Quantity = 100,000 Lb./Hr.
Heat Load = 97,000,000 Btu/Hr.
Condensing Temp. = 212°F

	Air	Water
U, Btu./hr., (°F) (Sq. Ft.) inside area	145	250
LMTD °F	76	117
Area Required (inside) Sq. Ft.	8,800	3,320
Capital Investment		
Cooling Tower (pro-rata share—9,700 gal./min. from 10,000 gal./min. tower at $200,000 complete)		$194,000
Exchangers (carbon steel installed complete)	$132,000	$12,800
Total Capital Investment	$132,000	$206,800
Operating Costs (annual)		
Cooling Water Makeup and Treatment at $0.005/1,000 gal. cooling water circulated		$25,500
Power at $0.006/Kwh	$12,200	21,600
Depreciation 7% on Exchangers	9,200	900
5% on Cooling Tower		9,700
Maintenance (1% on Air, 3% on Water)	1,300	6,200
Total Operating Cost per Year	$22,700	$63,900
Return on Investment 10% after Federal Tax at 50%	$26,400	$41,200
Total Operating Cost and Profit	$49,100	$105,100

Table 3. Evaluation of air vs. water as cooling medium for condensing exhaust steam at atmospheric pressure.

Below, air-cooled exchangers are installed at three different levels in a plant adjacent to the equipment which they serve. Approximately 75% of the total plant heat load is removed with units such as these.



Heat removal

continued

the air unit. Any fouling and corrosion is confined to the process side of the exchanger. For a cooling water unit, similar maintenance costs apply with additional costs due to: fouling and corrosion on the water side of the exchangers, repairs to the cooling tower, treating equipment, makeup and blowdown facilities, and circulating equipment. For our particular installation, the maintenance on the air units, excluding corrosion or fouling due to the process fluid, is about 30% of that for the cooling tower installation.

The main outlets for disposal of cooling tower blowdown are rivers, lakes, and man-made ponds. Where the water flow in rivers is small or intermittent, disposal of blowdown from cooling towers requiring extensive water treatment can present a hazard to wild life and domestic animals drinking the water. Disposal to lakes for evaporation, of course, entails the expense of purchasing or leasing the land and transporting the stream. The same cost applies to man-made ponds plus cost of construction, and possibly sprays to aid evaporation.

In the tabular examples, no attempt will be made to show the bearing of all of these factors on the overall economics. Some of the items, however, are more general and can best be illustrated by typical examples. The following cases are taken from our operating experience:

1. Condensing acetic acid
2. Condensing low boilers (organic chemical mixture)
3. Condensing exhaust steam
4. Condensing methanol at 15 lb./sq. in. gauge
5. Condensing methanol at atmospheric pressure

In each case a 10,000 gal./min. cooling tower with 105°F to 85°F range is assumed. A cost of $200,000 for the tower, basin, circulating facilities, and treating equipment is assumed, and a pro-rata share of this investment is used in each example. A design ambient air temperature of 100°F for the air cooled exchanger is used. The costs for both shell and tube and the complete air cooled units are taken from recent estimates from manufacturers.

The factors discussed do not include all the parameters one may consider in answer to the question, "What cooling medium should be used—water or air?" However, they do represent some of the more important considerations, and it should be clear from the examples used that the "automatic" selection of a cooling medium without careful study of all the factors involved can be a serious mistake. Conditions in different plants will favor some or all of the reasons for using the air or water route. But both routes should be considered for each new cooling job. Decisions based on proper evaluation of these factors will lead to increased plant profits.

Condensed from a paper presented at the Cincinnati Annual Meeting of A.I.Ch.E.

Quantity = 25,000 Lb./Hr.
Heat Load = 11,800,000 Btu/Hr.
Condensing Temp. = 147°F

	Air	Water
U, Btu./hr., (°F) (Sq. Ft.) inside area	95	160
LMTD, °F	34	51
Area Required (inside) Sq. Ft.	3,660	1,450
Capital Investment		
Cooling Tower (pro-rata share—1,180 gal./min., for 10,000 tower at $200,000 complete)		$23,600
Exchangers (carbon steel installed complete)	$54,900	6,000
Total Capital Investment	$54,900	$29,600
Operating Costs (annual)		
Cooling Water Makeup and Treatment at $0.005/1,000 gal. cooling water circulated		$3,100
Power at $0.006/Kwh	$5,000	2,500
Depreciation 7% on Exchangers	3,800	400
5% on Cooling Tower		1.200
Maintenance (1% on Air 3% Water)	500	900
Total Operating Cost Per Year	$9,300	$8,100
Return on Investment, 10% after Federal Tax at 50%	$11,000	$5,900
Total Operating Cost and Profit	$20,300	$14,000

Table 5. Evaluation of air vs. water as cooling medium for condensing methanol at atmospheric pressure.

Quantity = 25,000 Lb./Hr.
Heat Load = 11,350,000 Btu/Hr.
Condensing Temp. = 180°F

	Air	Water
U, Btu./hr., (°F) (Sq. Ft.) inside area	90	150
LMTD, °F	60	84
Area Required (inside) Sq. Ft.	2,100	900
Capital Investment		
Cooling Tower (pro-rata share—1,135 gal./min. for 10,000 gal./min. tower $200,000 complete)		$22,700
Exchangers (carbon steel installed complete)	$31,500	4,100
Total Capital Investment	$31,500	$26,800
Operating Costs (annual)		
Cooling Water Makeup and Treatment at $0.005/1,000 gal. cooling water circulated		$3,000
Power at $0.006/Kwh	2,900	2,400
Depreciation 7% on Exchangers	2,200	300
5% on Cooling Towers		1,100
Maintenance (1% on Air 3% on Water)	300	800
Total Operating Costs Per Year	$5,400	$7,600
Return on Investment, 10% after Federal Tax at 50%	$6,300	$5,400
Total Operating Cost and Profit	$11,700	$13,000

Table 4. Evaluation of air vs. water as cooling medium for condensing methanol at 15 lbs./sq. in. gauge.

Performance of Integral-finned duplex tubes

Edwin H. Young
and Marvin L. Katz
*University of Michigan,
Ann Arbor, Michigan*

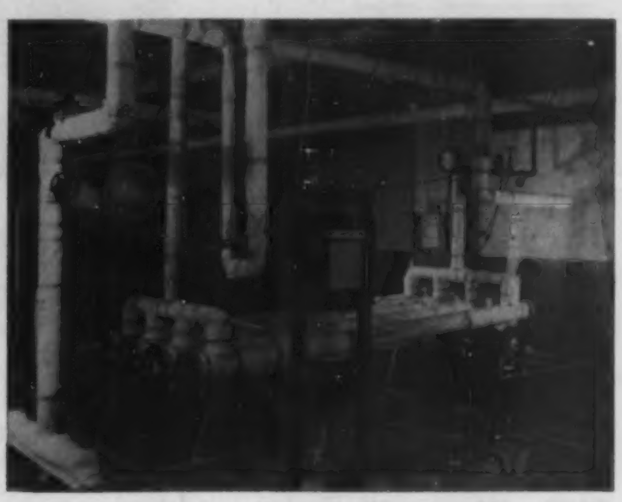


Figure 5. Hot oil cycling apparatus and temperature recorder.

AIR-COOLED HEAT EXCHANGE

This investigation involved the study of the effect of thermal cycling with steam to 350°F, and hot oil to 600°F, on the bond resistance of duplex integral-finned tubes. Twenty 10-ft. long duplex tubes, of the type normally used in air-cooling applications, were studied. As many as 12,000 thermal cycles were observed in some of the tubes. Eighteen of the tubes had ⅜-in., and two had ⅝-in. fin heights. The outer integral-finned sections were all-aluminum. All the tubes had 1 in. O. D. liners.

The phenomenon of bond resistance is discussed and an apparatus for its measurement is described. The bond resistances reported in the paper were obtained using a tube-side inlet water temperature of about 180°F, and a shell-side inlet water temperature of about 80°F. The bond resistance apparatus used a 5-ft. long x 3-in. diam. concentric-pipe heat exchanger, with high velocity hot and cold water flowing countercurrently. Correlations were developed for both the inside and annular heat transfer coefficients, using all-aluminum finned-tubes having physical dimensions similar to the duplex tubes tested.

The steam cycling apparatus and hot-oil cycling apparatus are described. The steam-cycling system tubes were cooled by 70°F water flowing through the tubes, using about an 8-minute steam-water cycle. The hot-oil cycles required approximately two hours with externally air-cooled tubes. Curves indicating the *variation in bond resistance* as a function of the *number of thermal cycles* are presented and discussed for: (a) four copper-liner tubes cycled to 350°F, (b) ten admiralty-liner tubes cycled to 350°F, (c) four admiralty-liner tubes cycled to 600°F, and (d) two steel-liner tubes cycled to 600°F. Figure 9 is a typical plot showing results of thermal cycling to 600°F with hot oil. The effect of thermal expansion coefficients and the amount of end-stripping were also studied.

The effect of bond resistances of various magnitudes on air-cooling operations is indicated. The investigation is being continued.

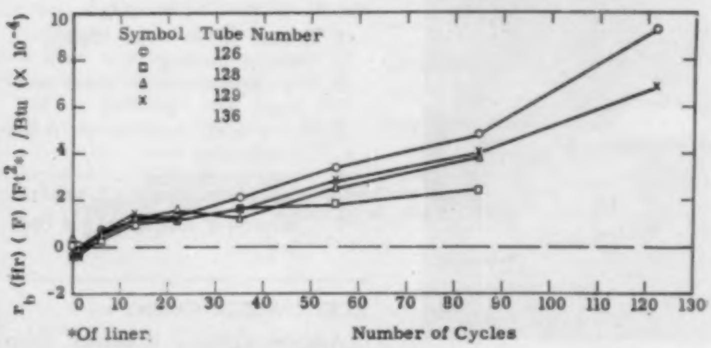


Figure 9. A typical plot showing results of thermal cycling to 600°F. with hot oil.

This article is abstracted from a paper given at the 1958 A.I.Ch.E. Annual meeting in Cincinnati. Complete text will appear in Symposium Series volume 24, is also on deposit at American Documentation Institute, number ADI 5859.

DESIGN

Optimum Air fin cooler design

Here are practical methods for computing and evaluating optimum air fin cooler design, considering the advantages and disadvantages of forced draft and induced draft units for specific applications.

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The two general classifications of air fin coolers are: the *forced draft unit*, where air is pushed across the finned tube surface, and the *induced draft unit*, where air is pulled across the finned tube surface. The primary advantages of the former is that for the same poundage of air moved, less horsepower is required. On the other hand, for the same poundage of air moved the latter unit will give better performance.

In a service where sudden temperature change due to rain, sleet, or snow would cause upsets and loss of product, such as in a high-purity product fractionator overhead vapor-condensing service, the induced draft unit would afford the most protection, in that only a fraction of the surface (as compared with the forced draft unit) would be exposed to rainfall.

A typical forced draft air fin cooler unit of Hudson Engineering Corp. In this installation the air is forced up across the tubes.

Generally, the use of air fins is considered feasible where cooling of a fluid to within 35 to 40°F of the maximum probable surrounding air temperature is desired. Where water supply is critical, air fin units may prove practical for cooling a fluid to within 20°F of surrounding air temperature.

Use of air fin coolers in series with cooling coils in a cooling tower merits consideration because high initial temperatures would cause excessive scaling.

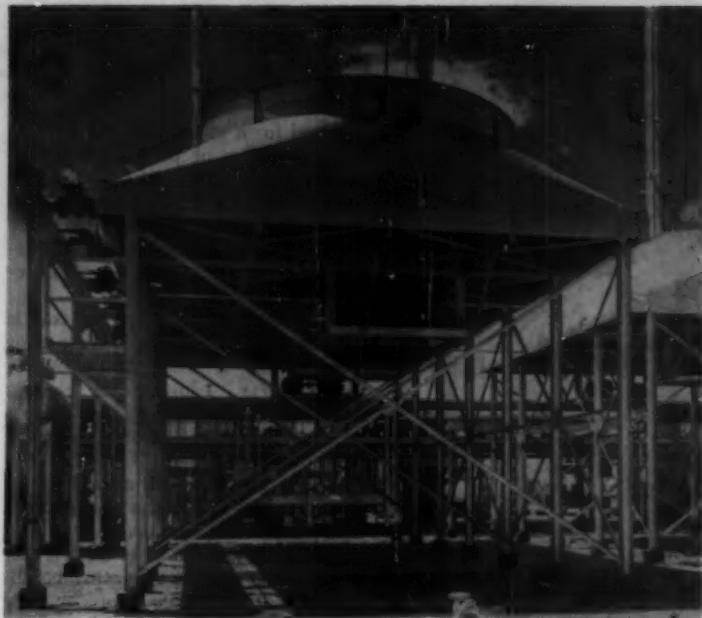
Listed below are some of the services in which air fin units are used in the natural gasoline industry.

1. Engine jacket water cooling
2. Lube oil cooling
3. Dephlegmator reflux water cooling
4. Heavy ends fractionator reflux condensing
5. Steam condensing
6. Reactor effluent cooling
7. Compressor discharge gas cooling

ACKNOWLEDGEMENT

Acknowledgement is hereby given to B. B. Brooks for his assistance in the preparation of this paper.

AIR-COOLED HEAT EXCHANGE



An induced draft air fin cooler unit of Hudson Engineering, where air is pulled up over the tubes.

Several methods used in air fin unit fluid outlet temperature control are:

1. Manually adjusted stepwise air flow by use of multiple fans and two-speed motors.
2. Temperature controller operated bypass around unit.
3. Temperature controller operated shutters.
4. Variable speed hydraulic motor or steam turbine operated by temperature controller.
5. Variable pitch fan operated by temperature controller.

Horsepower requirements to remove a fixed quantity of heat in a given unit vary drastically from design with changes in temperature. To take maximum advantage of the savings in power costs, use of multi-fan units and automatically variable pitch fans are recommended.

Automatically controlled shutters give good control, at the expense of power costs, as do bypass controls.

Use of variable-speed steam turbine drives where steam is available, or hydraulic motor drives with a master hydraulic pump, driven by a gas engine in remote areas, should be considered.

The following problem will be used for illustrating the following methods of calculation and evaluation.

Problem:

Determine the optimum size of unit for dephlegmator reflux water cooling at the following conditions:

Volume—800 gal./min. water

Temperature—Inlet 250°F; Outlet 150°F

Heat Duty —4×10^7 Btu./Hr.

Maximum Allowable Pressure Drop —10 lb./sq. in. gauge

Fouling Factor—0.001

Location—Plant X in West Texas at 3,000 ft. elevation

Premise—Use 103°F design air temperature, auto variable pitch fans, and 30% minimum annual rate of return required.

Computing horsepower required vs. size

Step One: Basic Data

Since air fin units vary with respect to coil size, tube pitch, fin heights, fins per inch, etc. for each manufacturer, it is necessary to obtain sufficient data from them to make a table of physical data, Table 1, and a plot of core face velocity vs. air side film resistance (reciprocal of heat transfer coefficient) related to bare tube surface and static pressure drop, Figure 1. From any number of sources, data required to make a plot of water velocity vs. water side film resistance related to bare tube surface and water pressure drop can be obtained.

Step Two: Calculations

Using Table 1 and curves of Figure 1, calculation can be made of various horsepowers required for air fin unit size combinations that will do the given job.

This is done by assuming a quantity of surface, tube arrangement, and size. Water side pressure drop is then checked for this assumed arrangement. A core face velocity is also assumed, and the surface required is checked against that assumed by trial and error. For this calculation, the air-temperature rise, the LMTD, and the final over-all heat transfer coefficient from Figure 1 and standard sources are determined. The required surface is then computed and compared with that assumed. The horsepower required for the assumed unit size and arrangement is then calculated. A number and size of fan is specified. The air horsepower is then determined from the air volume, static pressure, and velocity pressure. The total horsepower is computed from fan and gear or V-belt efficiencies.

Evaluating horsepower requirement vs. size

Step One: Operating Cost

The operating costs are determined for various unit sizes by use of the following equation:

Total operating cost = a b c d e.

Where:

a. **Horsepower required at design air temperature** is computed by the method outlined above.

b. **Horsepower correction factor** is determined in two steps: First, the effect of air temperature on horsepower

continued

Table 1. Physical Data for Coil Sections Using 1 In. O.D., 18 Gauge, 2-1/16 In. Sq. Pitch Tubes with ½ In. High Al. Fins, Spaced 9 Fins/In.

	For 5 ft. wide hdr. coil	For 7.75 ft. wide hdr. coil
1. No. tubes per row	29	45
2. Cross sectional area/row, sq. ft.	0.129	.200
3. Core face area/ft. of tube length, sq. ft.	5.00	7.75
4. Bare tube surface/ft. of tube length/row of tubes, sq. ft.	7.59	11.78
5. Total extended surface/ft. of tube length/sq. ft.	103.8	161.6

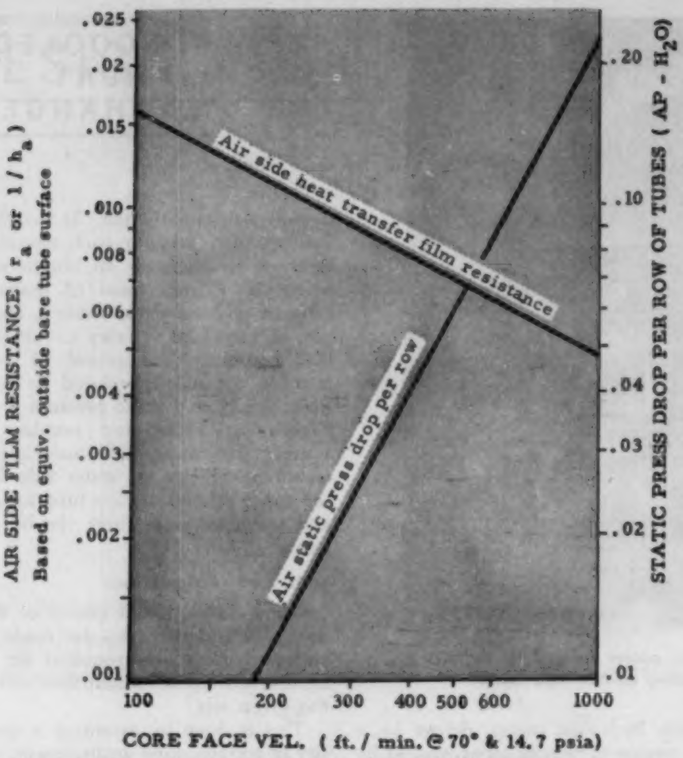


Figure 1. Approximate film resistance and static pressure drop vs. core face velocity for 1 in. O.D. tubes with 9 fins/in. ½ in. high Al, 2-1/16 in. sq. pitch.

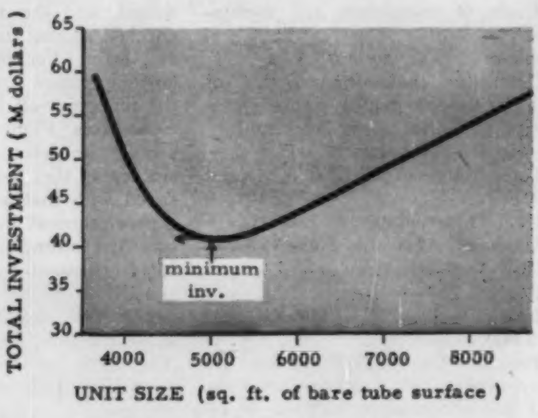


Figure 2. Air fin unit size vs. estimated total investment cost.

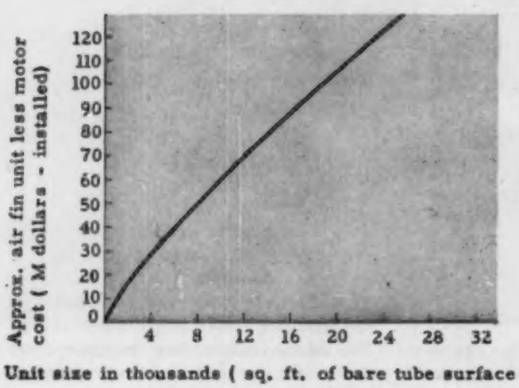


Figure 3. Air fin unit size vs. estimated cost of unit installed.

Air fin cooler

continued

required for a given size unit is computed in terms of percent of design horsepower required. Second, the percentage of time during the years, in increments between the maximum and minimum temperatures is determined* by use of temperature-plots for the location.

c. **Annual purchased power cost** is computed from average Kw rates for a particular location, in terms of dollars/hp/yr., allowing for electric motor efficiencies. For the sample problem, the annual cost/hp., of $73 is used.

d. **Expected life of a unit** is an arbitrary figure. For the above problem, 20 years is assumed.

e. **Maintenance** is an estimated cost to keep the unit in operating condition. For the sample problem it is assumed to be negligible.

Step Two: Minimum Investment

The minimum investment cost is determined by plotting the total investment cost for the various unit sizes. There will be a point where investment reaches a minimum, ($40,500 for the sample problem), Figure 2.

Total investment cost is the sum of estimated, installed cost of air fin unit (without motors) plus the estimated, installed cost of the electric motors (including starters and wiring.) An estimate of installed air fin units (without motors) for various unit sizes is shown in Figure 3.

Step Three: Justification

Determine the amount of additional money that can be justifiably spent for a larger-than-minimum investment unit, based on savings in operating cost. For the sample problem, an additional expenditure of approximately $2,000, or a unit size of 5,800 sq. ft. is justified. The 5,800 sq. ft. unit represents the optimum design size.

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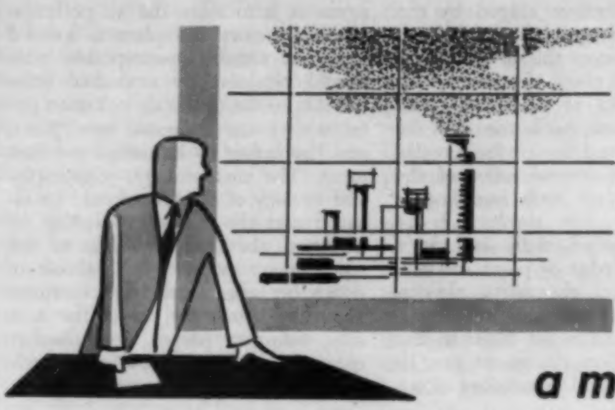
* *Taking the summation of the percent of time per year at incremental temperatures, multiplied by the corresponding percent of design horsepower required, will give the horsepower correction factor. For the above sample problem, the correction factor is 28.5%.*

Condensed from the paper, "Finding the Optimum Air Fin Cooler Design for a Given Job," presented at the A.I.Ch.E. Annual Meeting in Cincinnati.



Air pollution abatement

a management problem

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Industrial executives who can safely ignore the increasing demands for air pollution abatement are becoming rare. This applies not only in the chemical process industries, the metallurgical, cement, ceramics, public utility and transportation fields, but in the factories whose only contributions to polluted air comes from the burning of fuel for heat or power. In some cities (Los Angeles, Chicago and New York), operations producing no atmospheric emissions join the line-up because of exhaust gases from company trucks and employees' cars.

Industry cannot rest on the laurels won by its leaders, nor take refuge in the fact that more than one-half of the nation's man-made pollution comes from the public's domestic heating, rubbish disposal, and transportation. Industry at large must follow its leaders in curbing its share of the national annual bill estimated at \$65 per capita, or \$11 billion in total.

Management's problem

From hundreds of cases in which companies have dealt, and are dealing successfully with air pollution abatement, come conclusions which can guide managers of less fortunate companies and those whose problems may be only in the making. For example where industrial air pollution problems have become so acute in poor locations, and additional investments and costs so high, that a plant can no longer compete, the solution is to shut down! In other cases, expansion at a given location becomes a problem in economic balance. If there is a prospect of either situation, owners of the business, as well as the chief executive, should be concerned.

It is submitted that any problem possessing the following characteristics qualifies as a proper concern for the chief executive:

An operating cost, not producing direct manufacturing profit.

A probable requirement for substantial capital investment.

An impending cost susceptible of control and minimization, particularly one in which top management takes the initiative and gets the word all the way to the operator whose hand is on the valve.

Affects location and design of new plants to maintain competitive position with those already favorably located and designed.

Affects plant and community relations, and good will; internal and external.

May, if neglected, lead to expensive lawsuits.

IN-PLANT
Pollution Control

What can management do?

Establish policy. Under today's prevailing conditions, prudent management will prepare its own statement of company policy on air pollution abatement, and promulgate this statement in terse, lucid form throughout the organization. This should be done even where no air pollution problem is known to exist at present. Problems can develop rapidly today in unexpected quarters. Notwithstanding the absence of a recognized problem at the moment, policy should require that the potentials for a problem should be carefully evaluated by a team within the company's own organization. One executive put it this way: "We don't look for trouble — we try to avoid it."

If qualified personnel are unavailable, it may be desirable to employ assistance to thoroughly scrutinize company activities contributing contaminants to the atmosphere. In some areas, "company activities" may include the operation of motor vehicles, rubbish disposal, company-sponsored residential areas, and even the operation of cars privately owned by the company's employees.

The survey committee's report, with findings and recommendations, should be submitted to top management. A definite determination can then be made as to whether the company has a present or impending air pollution problem, and if so, whether

continued

Air Pollution

continued

its dimensions are such as to require immediate remedial action. Even when no action is indicated wise management policy will provide for periodic review.

The establishment of a company policy with respect to air pollution abatement is so indispensable to the company's future welfare that its importance cannot be exaggerated. A *general* statement to the effect that "the company is unalterably opposed to harmful air pollution arising from its activities," however clothed in ringing platitudes, has been unproductive. Sound policy can result only from a solid foundation of knowledge, rarely available at the outset. Accordingly, policy develops from a "let's get the facts" beginning, to a well-informed, well-worked-out "company code," in which personnel assignments and practices are clearly spelled out.

Air and stream pollution differ

Back of the company policy is a growing understanding by management of the characteristics of present-day industrial and community **air pollution** problems. In several respects they differ substantially from the older, and better known, **stream pollution** problems, hence require a unique approach to policy.

For example: air pollution is not confined to one river or lake; air pollutants are distributed over a large radius from the plant site by the vagaries of the weather. Somebody in the company must have a working knowledge of meteorology. Chemical and physical analysis of stack gases and other effluents require unusual techniques, including: the collection and identification of solid and liquid particles (aerosols) smaller than the average wave length of visible light; and the measurement of concentrations of contaminants three orders of magnitude more dilute than we commonly measure, yet possessing significant toxic, corrosive, or nuisance effects. Special scientific equipment often must be employed, such as; infrared, ultra-violet, mass spectographic, and other complicated optical equipment; gas chromotography; and special equipment for collecting samples which are meaningful. The engineering equipment used to accomplish air pollution abatement is more complicated and diverse than that used in treatment of liquid effluents, involving a great variety of mechanical, electrical and chemical devices. This means that the day is past when the dimension of the company's air pollution problem could be estimated merely by odor or visible appearance, whether judged by the plant personnel or by the neighbors.

Merely to survey the environs of a manufacturing plant, frequently involves sampling of vegetation, animals, soil, water, air-borne and deposited dusts, and the air itself, within a radius of several miles of the plant site. Unless such sampling is done properly, the results can be expensive. Needed skills include a working knowledge of plant and animal physiology, chemistry, physics, and a lot of scientific resourcefulness. But management is not fazed to find that air pollution abatement can be as complicated and demanding of scientific skills as the company's regular manufacturing problems.

When there is a problem

Anticipate the problem. Fortunate is the management with the foresight to be the first to discover that the company has a *problem*. In this case the chances are good that it will have the time to develop the facts fully; to determine the optimum remedial program, and to design any required facilities with a minimum disruption of its engineering, research, and operating personnel. Deliveries of required equipment can then be normal, and the program can be routinely scheduled. Under these conditions, management can maximize the probability of securing the best answer to its problem, and minimize the capital investment and operating costs for achieving it.

The ultimate goal of skillful management is to solve the air pollution problem before the plant is located or built. Otherwise-acceptable sites should be carefully evaluated from the standpoint of the air pollution potentials of the proposed new plant, and the urban or industrial environment. The meteorology, topography and ecology of the area should be assayed and the cost of providing air pollution abatement suitable to this environment estimated. This cost of doing business must be determined and added to other costs for each site, before a proper determination can be made of the lowest-cost production point. An otherwise-ideal location could, if it required an investment of several million dollars for control equipment, load costs with an intolerable burden. Once a site has been chosen, base levels of existing pollution should be established by surveys during a period of 1-2 yr. before plant start-up. Finally, the engineering of necessary air pollution controls into a new plant design will pay off, not only in minimizing direct costs, but in starting off on the right foot in the new community.

The crash program

Management is not always so fortunate, [i.e., foresight] and frequently is confronted rather abruptly, by a problem of huge dimensions; the seri-

Penalties vs. Prevention

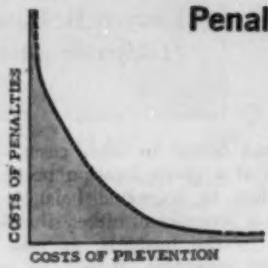

Figure 1. Relation between abatement costs and costs of penalties for pollution. Without abatement efforts, penalty costs become extreme. On the other hand there is a point above which increased abatement measures become exorbitant.

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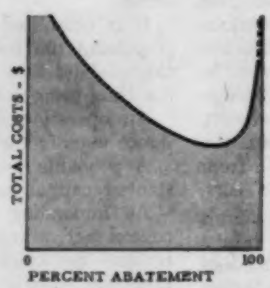


Figure 2. A minimum total cost can be estimated. While purely qualitative, it is important to note that minimum total cost corresponds to a substantial degree of prevention.

ousness of community complaints may have been underestimated, or minimized; hearings are held and laws passed before the company has an opportunity to get the facts and to marshal its defenses, let alone take corrective action; company officials are presented with notices of violations and may have to fight for time in which to work out an acceptable, though hurried, program into which they find themselves forced.

Some companies have discovered that they had a *real* problem when, what had been considered unfounded complaints, blossomed into a crop of lawsuits. While charges of violation and the filing of lawsuits is far from proof of guilt, these crises are apt to be expensive and can lead to costly "crash" programs. One large metallurgical plant, confronted four years ago with suits totaling $25 million, reportedly settled these suits recently for $25,000, but in the meantime had spent $10 million on capital investment for corrective facilities, and an estimated $2 million in research, legal fees, and payments to farmers.

Preventive measures are often costly, but prove to be wise investments. Figure 1 illustrates the typical relationship between such costs and the penalties of alternative costs; represented by lawsuits, damages, shutdowns, losses of process materials and good will. With no corrective steps, penalties can be intolerably high (including moving away). At the other extreme, air purification can be carried beyond the abatement of a nuisance and become equally exorbitant; 80% reduction can cost $1 million and be adequate; the next 10% can cost $4 million and accomplish little more of practical value.

By combining costs of prevention and penalties, Figure 2, a minimum total cost can be roughly estimated. While the illustration is purely qualitative, it is important to note that:

1. minimum total cost typically corresponds to a substantial degree of prevention
2. costs decline rapidly up to that point [minimum]

Define the problem. Granting that an actual or potential problem exists, the first step is to define it. This requires full information about the company's emissions, including: total quantity, rate, concentration, physical and chemical properties, and data with respect to the toxicology, corrosive properties, or other characteristics determining the seriousness of the nuisance. It is desirable to run material balances in process industries.

Consideration should then be given to the character, quantities and concentration of air contaminants originating from other sources in the neighborhood. This work should be done objectively with a willingness to accept full responsibility for nuisance or damage arising out of the company's own activities. Much can be gained by working with local air pollution control agencies, which are likely to have pertinent data and experienced technical personnel.

Allegations of air pollution abuses have, on occasion, been made unjustly. For example, in a northern community whose only significant industry consisted of two steel plants, the public became greatly aroused over the soot and smoke problem, for which the steel plants were blamed. In this example of community relations, the facts were developed and made known to the local press. The steel mills used electric furnaces, creating no pollution, while the community used bituminous coal for its domestic heating. The smoke and soot of which the public rightly complained were of their own making. The problem had been defined.

Definition of the problem is not always so simple. The collection of adequate data as outlined above, requires equipment and men skilled in its use. If they are not already part of the company's organization, these men must be found and, perhaps, trained. Sampling and analytical equipment frequently have to be devised—no job for a greenhorn.

Studies needed

Among the studies specifically needed to evaluate the problem are:

Meteorology. A *wind rose* should be prepared for the plant site, showing the frequency and velocity of the winds in various compass directions at different seasons. Frequency and duration of temperature inversions may be important, including height to base of inversion.

Rate of Emission. Emission rates of gases, dusts and aerosols vary widely over a 24-hr. (or other) period. The concentration ranges must be known since peak emissions are often the sole cause of trouble.

Survey of Environs. As emissions are dispersed from the plant by convection, concentration patterns must be determined, at distances dependent on the rate of disappearance; profiles are then correlated with meteorological data. Dust-fall/unit area provides further essential evidence.

Physiology. Studies of the physiological effects on vegetation, animals and humans may be necessary, especially when these effects are not known for a pollutant. Investigations can be carried on by pathologists in the company's own facilities or at outside institutions.

Where the company's plant is located in an industrial or urban area, distinguishing between sources of causative agents responsible for complaints introduces further complexities. If adequate technical help is not available within the company, and time is pressing, the services of outside professional agencies can usually be employed until the company can provide its own.

In spite of its best efforts, however, a company is likely to find that it takes many months to define the problem adequately. Some recent major examples have taken two to five years. Where *special circumstances* force action in advance of proper definition, large sums can be spent and irrecoverable time lost, with no effect on the basic causes. Fortunately, in many states and communities today, it is recognized that these problems are of a pioneering nature. As long as the company genuinely demonstrates "due diligence," **and keeps the authorities and the community informed of its progress,** it may expect time to work out an acceptable solution.

It is an old saying that **the problem defined is half-solved.** Certainly, definition is a major step in the right direction. In the case of a large steel plant with a fluoride problem, definition of the problem took perhaps a year; and a crash program of large-scale engineering research, culminating in a major construction project, took at least two more years. Much of this work was pioneering. Experience is now available enabling many problems, once defined, to be solved more quickly.

Determine action to be taken. Assume that a company's emissions to the atmosphere and resulting nuisance or damage have been determined. Means must then be found to reduce such emissions to acceptable levels. If suitable means do not exist, they must be developed. Engineers experienced in air pollution control equipment are required in either case. As a result of their studies, estimates can be developed for capital investment and operating costs corresponding to given reductions of the offending contaminant. Alternatives may include process changes in which raw mater-

continued

Air Pollution

continued

ials, solvents, or operating conditions are changed. On the basis of these calculations, and knowledge of levels acceptable to the community, management can then select the method which provides the maximum improvement at a cost which the company can afford.

This is a major decision. In arriving at it, management may confer with community leaders if the complaints have been based largely on aesthetic objections, and together weigh the economic role of the company as a continuing member of the community against the consequences of moving away. Fortunately, adequate remedies are usually available at costs which can be handled without undue hardship. Solutions may be found in which the recovery of materials serves to reduce the total cost of the program. Management increasingly finds its rewards in the more intangible but valuable benefits of good community relations.

Provide competent personnel. Ordinarily the company organization should include at least one competent full-time air pollution engineer. Rare is the manufacturing plant today which can safely assign this problem as a part-time duty. A process industry plant of any size usually also requires one or more younger engineers, and chemists to carry out the often complex sampling and analytical procedures.

Competent technical men with professional experience in air pollution control engineering and in many auxiliary subjects of specialization are neither readily available, nor can they be trained overnight. As in many other fields, qualified personnel have learned "on the job". Therefore, in staffing the air pollution abatement activity, management must often look to individuals with good basic training in some branch of engineering or the natural sciences. Chemical engineers have assumed a leading role in this area, often because of their knowledge of processing relating to pollutant-emission.

Education and training

Many of today's competent air pollution men graduated in chemical or mechanical engineering, or at least hold bachelor's degrees in chemistry or physics. A few universities offering graduate degrees in sanitary engineering are providing some of the specialized training in their curricula required by pollution control engineers. In addition to formal education, several years of industrial experience in plant operations or research and development are needed before one can tackle an air pollution abatement assignment. A good man with this type of background should, with intensive application to existing literature and to the job under experienced supervision, become independently effective within one to two years. Five years more may qualify him for responsible charge of this important activity, provided he possesses the necessary attributes of leadership and administrative ability.

Aids to development of such personnel just described include: membership in professional societies, attendance at technical meetings (especially those devoted to industrial air pollution problems), and extensive reading of the technical literature.

Comprehension of our air pollution problems (imperfect though it may be), would be virtually non-existent were it not for the contributions our technical societies have made to the enlightenment of industry, the public, and government at all levels. Oldest among these is the Air Pollution Control Association, a national body which has done much to stimulate research, to disseminate information, at least within professional circles, and to bring together representatives of control agencies, and of alert companies. It holds semi-annual national meetings and occasional local section meetings. In cooperation with the Library of Congress and the Public Health Service, it publishes monthly abstracts of the world literature, of inestimable value to workers in this field, and a quarterly journal.

Nearly every technical society has its air pollution committee. Among the best known are those of the American Institute of Chemical Engineers, the American Society of Mechanical Engineers, and the American Chemical Society. The pollution control engineering committee of A.I.Ch.E. is currently headed by W. L. Faith. These societies frequently present comprehensive symposia on abatement technology. The Engineers' Joint Council recently issued a masterpiece of terse and lucid exposition in its "policy statement on air pollution and its control." The statement prepared by a special committee representing nine major engineering societies, chaired by C. A. Bishop of A.I.Ch.E, summarizes desired goals in a manner useful to management, the pollution-control staff, and local governmental forces.

IN-PLANT Pollution Control

The Manufacturing Chemists Association coordinates the technical efforts of its member companies, keeps up-to-date an encyclopedic "Abatement Manual," and has published a booklet, "A Rational Approach to Air Pollution Legislation."

The American Petroleum Institute has a large and active "Smoke and Fumes Committee," which sponsors progress reports at Institute meetings, and research projects in universities and other outside organizations to the tune of $1 million per year.

The American Iron and Steel Institute sponsors pollution research bearing directly on problems of this industry. Research to understand and control motor vehicle exhaust-gas pollution is sponsored by the Automobile Manufacturers Association, and published by the Society of Automotive Engineers.

The federal government, through the Public Health Service of the Department of Health, Education, and Welfare, sponsors frequent conferences and offers training programs covering a wide range of air pollution abatement techniques. A conference for the chemical industry was conducted jointly with the Manufacturing Chemists Association in Cincinnati, March 18-19, 1959.

Physiological effects are reported at meetings of the American Association of Industrial Hygienists and the American Standards Association.

The greater part of the scientific and engineering research reported by these technical societies and published in their journals is conducted in industry's own laboratories, or in those of universities and independent research organizations with industrial support. Direct contact with these institutions, which conduct periodic progress report meetings for the sponsors is helpful in training. Valuable on-the-job training can also be provided under the guidance of qualified consultants employed by the company to assist in their air pollution abatement program.

Special professional services are usually required to supplement the work of the regular personnel mentioned above. Meteorologists, animal

and plant pathologists, industrial hygienists, and statistical analysts are typical of these specialists. Large companies may have them on their permanent staff; others hire them on a part-time, contract, or consulting basis.

The organization chart

An air pollution problem at one plant. The air pollution engineer commonly reports to the plant manager, who arranges with other plant departments to provide necessary assistance. Practices differ widely between companies. In some the responsibility for air-pollution abatement is given to the chief engineer, director of research and development, chief chemist, or chief of the process control group. Having the pollution control man report to the production manager is as objectionable as having "Inspection" report to this individual.

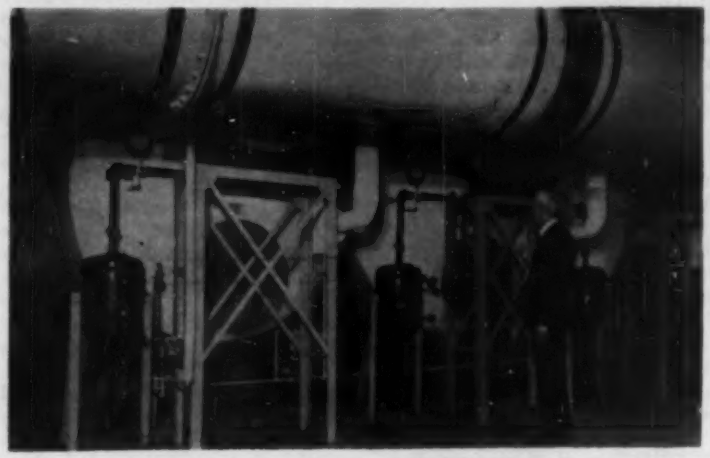
In any case, primary responsibility for securing and maintaining adequate air pollution abatement should be placed unequivocally on the shoulders of a vice-president, or other key man, who can be relied upon to give the assignment the full attention it deserves. Unless the problem has already been analyzed, and found to be a small one, adding it as a part-time duty at a lower level is unlikely to prove satisfactory.

Air pollution problem at more than one plant. In the multi-plant company having air pollution problems in several plants, the company should have an air pollution engineer on the staff of top management, available to work with the managers and air pollution engineers of the affected plants. In some companies he reports to the staff chief engineer, in others to the medical director or chief of industrial hygiene. A company-wide advisory committee reports to an executive vice-president or other top official. Members usually include representatives of operations, engineering, legal, medical and public relations departments. With the principal air pollution abatement man, this comittee serves to integrate company resources in achieving a well-considered solution.

Companies also having stream pollution problems may combine these responsibilities with air pollution abatement, but preferably above the working level in the plant. In so doing the company should recognize the different requirements of the two types of problems.

Public information

The importance of informing the authorities and the community of the company's own progress has already been stressed. But beyond this, industry needs to interpret its principal findings to the public in simple lucid terms. The technical literature of the world abundantly documents industry's achievements in air pollution abatement. It is perhaps because this essential industrial progress has been largely reported in technical magazines, that the lay public is unaware of it. Articles in the lay press, on the other hand (sometimes written with little knowledge or understanding of these technical papers), tend to reflect uninformed, subjective, and emotional attitudes to community air pollution. Such articles have led to mass hysteria, hasty legislation, and other futile activities which have impeded rather than furthered progress toward a real solution.



As seen here, equipment for air pollution prevention can become complex. It is management's job to balance the cost of abatement measures with the actual increase in effective control. There is a definite point of diminishing returns.

Finally, assuming that a competent and process-experienced chemical engineer is appointed to be the team leader (carry the primary responsibilities) in your company for pollution control, don't overlook the value of making him your "expert" in the eyes of the local, as well as the industrial and [his] professional communities. A competent technologist who can tell widely varied groups the good work he is doing for your company is a priceless asset.

Companies with no previous experience in handling air pollution problems would do well to seek the counsel of others who have dealt extensively and successfully with such problems. Good advice is often available from others in the same industrial group; from trade associations, technical societies, and consultants specializing in this field.

Some companies, reluctant to let it be known that they have a possible air polution problem, attempt to cure it secretly, only to find that their inexperience leads them into expensive or ineffective programs. Taking competent counsel into their confidence may reveal that their apprehensions were unfounded. Air pollution abatement, like other technical problems, is subject to the hazards of the do-it-yourself approach.

Furthermore, recognition of a possible air pollution problem by a company is no longer a disgrace, but a mark of progressiveness. As many industrial leaders have said in recent years, "Air pollution abatement is good business."

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In-plant pollution control in practice

2. Pulp & Paper Industry

H. W. Bialkowsky
Weyerhaeuser Timber Co.
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SINCE 1946, the wood pulp capacity of the United States has increased at an average rate of 1.1 million tons/yr. and in 1956 the United States wood pulp production reached over 22 million short tons for the manufacture of paper and paperboard. For the past five years, between 8 and 9 million tons of waste paper have been reclaimed each year, and along with slightly over 1½ million tons of rags and other fibers, the total fibrous materials consumed in the manufacture of paper and board reached a figure of 32 million tons *(1)*.

Several million tons of chemically-produced wood pulp are also consumed as raw materials in other fields such as textile fibers, cellophane, lacquers, etc., and the total wood pulp capacity of the United States has jumped from 12 million tons in 1946 to 26 million tons in 1957. A breakdown of this growth in chemical pulps shows that **sulfate or Kraft** capacity rose from 5½ million tons in 1946 to 13¾ million tons in 1957. **Sulfite** capacity rose from 3 million tons in 1946 to slightly over 4 nullion tons in 1957. Approximately 3½ million tons of neutral sulfite capacity from the hardwoods was added during this ten-year period. The rapid growth of the Kraft (sulfite) process is due primarily to the fact that new wood species were available for pulping, which could only be pulped by the Kraft process. A secondary reason for this growth was that the Kraft pulping process has highly developed chemical and waste salvage recovery systems. The rapid growth of the so-called **neutral sulfite semichemical** process reflects the availability and utilization of new hardwood species as an excellent raw material for corrugating medium in corrugated board. The major processes under consideration, therefore, in the order of their importance are: sulfate, sulfite, and neutral sulfite.

Pollution loads

In the case of the **bleachable pulps** from both the sulfite and Kraft processes, the material is bleached with chlorine compounds, usually by direct chlorination, followed by combinations of dilute caustic extractions and hypochlorite bleach. The material is washed between the various bleaching steps, and the dissolved lignin residues and soluble carbohydrate fractions are contained in the wash waters in extremely dilute form.

The pollution load for sulfite pulping can be estimated from the pulp yields in amounts of 1.25 to 1.5 tons of organic waste/ton of pulp produced, depending on the pulp yield. The BOD varies from 450 to over 1,000 lb. O_2/ton of pulp, depending on wood species, and type of pulp produced. As Kraft process yields are only slightly lower than those of the sulfite process, the Kraft waste liquor organic content is substantially the same as that in the sulfite process, and it would carry substantially the same oxygen load if recovery processes were not employed.

IN-PLANT Pollution Control

Table I summarizes the range of 5-day BOD oxygen loads for the various pulping processes and the oxygen loads for the various types of bleach effluents. Here, the characteristics of the cooking residues are based on the unbleached pulp whereas the bleaching residues are on a bleached pulp basis.

With **chemical pulp** yields in the range of 40 to 50%, the amount of organic residues in effluents exceeds, or is equal to the actual pulp production. Over the past 50 years, vast research and development work has been done on ways and means of utilizing this material (2). Over half of this material is associated with the unknown structure of the lignin molecule. Liquor also contains both fermentable and non-fermentable carbohydrates. Various schemes have been proposed and are in limited use for making alcohol and fodder yeast from the fermentable portions of the carbohydrate residues. Many lignin preparations and derivatives have been made which include vanillin and its derivatives. One of the big problems in utilizing the spent cooking liquors for by-product recovery is that only certain fractions are usable, and large portions of the original residues are still discharged as effluent. For example, in the manufacture of alcohol and fodder yeast only fermentable sugars are used, and although this represents a substantial reduction in 5-day BOD, there still remains a larger percentage of the total organic residue.

Another approach to this problem

is the use of these organic residues for steam and power generation, along with the direct and efficient recovery of the cooking chemicals for re-use.

Many schemes for the recovery of chemicals have been described (2). These involve the use of bases other than Ca, such as NH_4, Na, and Mg.

Fiber losses and other suspended materials in the white waters are also of concern to the pulp and paper industry. By the proper re-use of water, fresh water is normally introduced near the end of the process countercurrent to the stock flow, such as on the pulp drying machine or paper machines, and the excess water is progressively used in bleached screening, bleach plant washing, unbleached screening, and ultimately in unbleached washing. Where waters cannot be re-used they are normally passed through various types of mechanical save-alls or flocculation systems. Losses in the **groundwood pulp industry** are of a similar nature and handled in a similar manner; in the hydraulic barking of logs and slab wood, the bark material is salvaged through coarse screens and the refuse pressed and sent to the boilers for power generation. Since large quantities of water are used in hydraulic barking, secondary screens are also used for reclaiming the fine bark particles and for minimizing the build-up of bark-sludge banks adjacent to the mill site. Here again, these problems are of a mechanical nature and while these lossses are of significant importance, they are relatively small compared to pollution loads in cooking and bleaching.

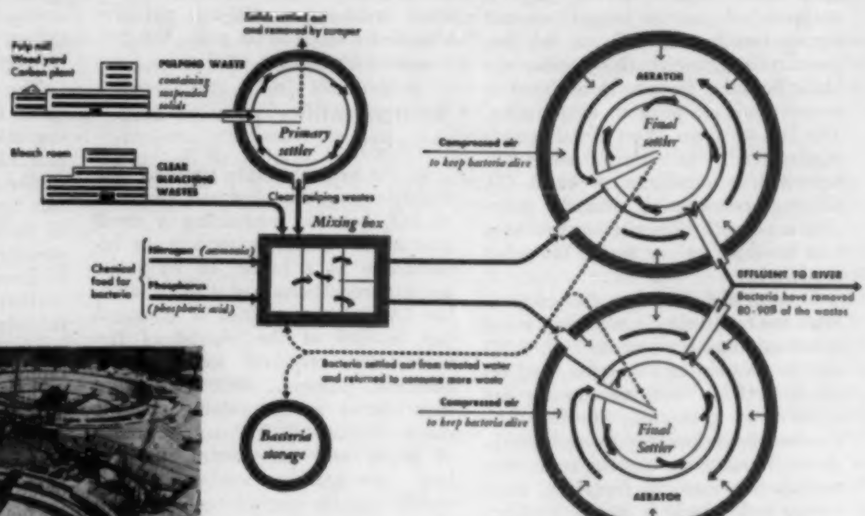
In reviewing the subject of pollution abatement in this industry by in-plant process changes, an effort is made to cover not only the process changes for minimizing overall wastes, but also to discuss process changes for general stream improvement, along the lines of the broader aspects of pollution.

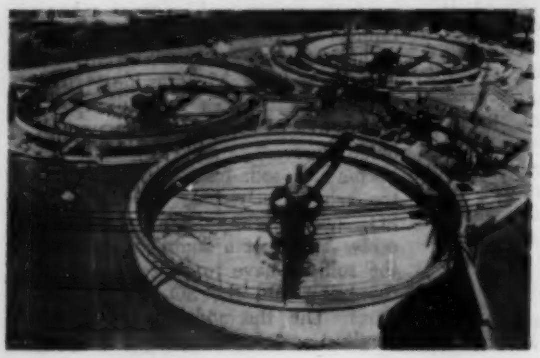
Kraft process

The Kraft pulping process is a cyclic system wherein the chemicals are recovered for direct re-use and the dissolved organic residue is burned for steam and power generation. Alkaline cooking agents used in the process are NaOH and Na_2S, with 16 to 20% active alkali consumed on a wood basis. With these quantities of sodium salts, it is necessary to effect some sort of chemical recovery to make the system economically feasible. After digestion, the pulp mass is blown directly into the blow tank. These contents of the blow tank are diluted with "black" liquor (spent cooking liquor) and the pulp is separated by filtration screens. The pulp is washed with three to four vacuum stages, with wash water (usually clean hot water from the surface condenser of the blow tank system) flowing countercurrent to the pump. Resulting waste liquor at 14 to 16% solids content, and at volumes of 2,000 to 2,500 gal./ton of pulp, is then sent through multiple-effect evaporators, where it is concentrated to about 45 to 55% solids content; then passed to a direct-contact evaporator of the cascade or cyclone type, adjacent to the recovery furnace. Here, the remaining heat of boiler flue gases concentrates the liquor further to 55 to 65% solids. Resulting liquors are then sprayed into large recovery furnaces in which the organic material is burned; and sodium salts are recovered at the bottom of the furnace as a molten smelt of Na_2CO_3 and Na_2S.

Makeup chemical is usually added to the furnace in the form of Na_2SO_4 and combustion conditions are regulated to reduce it to the sulfide. Mechanical losses occur in the furnace due to dust or fume carry-over of sodium salts, and much of this material is recovered from the flue-gas breeching system by an electrostatic precipitator or a venturi-type scrubber. (3)

After dissolving, the smelt (green liquor) is treated with lime to form the cooking liquor (NaOH and Na_2S). After settling and decantation the clear liquor (white liquor) is ready for subsequent cooking re-use. The lime mud is washed and re-burned in a rotary kiln to provide a regenerated lime for causticizing.





Waste treatment plant at the Covington, Va., plant of West Virginia Pulp and Paper Co. Above, the flow diagram.

Pulp and Paper

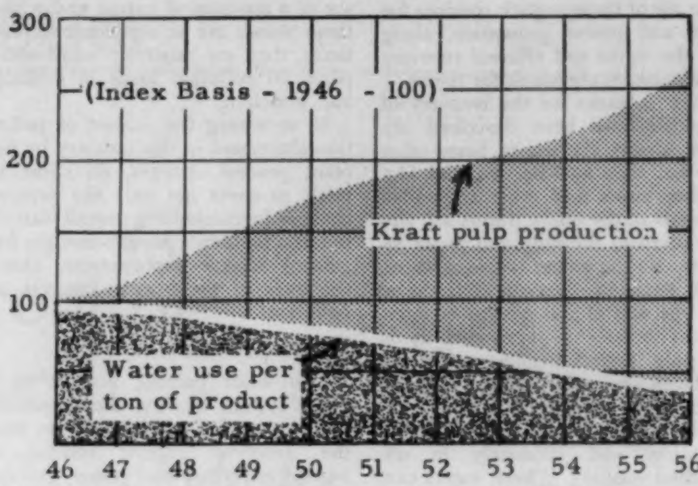
continued

As the Kraft pulping operation employs large quantities of sulfur compounds, malodorous compounds are generated in both the cooking and recovery operations. During digestion, some of the sulfide radical reacts with methyl groups of the wood components with the generation of methyl mercaptan, methyl disulfide, dimethyl disulfide, as well as methyl alcohol, acids, and other breakdown products of the pulping treatment. These volatile compounds appear in the digester relief condensates, the blow condensates, and the evaporator condensates representing about 3 to 5% of the weight of the original wood substance. As these materials are volatile they are not readily picked up by conventional gravimetric means and they are frequently overlooked in material balance studies.

In addition, some H_2S is generated, in the digestion and evaporation steps. These materials are not completely condensed in the digester blowing operations and they also appear in the condensates during the evaporation steps. Methods of combating atmospheric pollution by collection, burning, and otherwise treating these materials have been described. (*4*)

As normal recovered liquor contains some residual sulfide, H_2S is stripped off in the direct contact evaporators by the CO_2 of the flue gases. To minimize this action, the black liquor is frequently oxidized in towers with air prior to evaporation. The liquors from West Coast woods oxidize readily in a simple tower system with a minimum of foam (*5*), although considerable difficulty is experienced with liquors from Southern woods due to excessive foaming tendencies.

Despite the fact that the condensates are relatively clear-colored water solutions, they do contain high BOD and in addition, the inorganic and organic sulfides and mercaptans are quite toxic to aquatic life (*6*). The condensates, especially those from digester blowdown, contain some turpentine-like material from the wood resins and which is steam distilled. The relief and blow condensates are, therefore, decanted and the turpentine recovered as a by-product or burned in the recovery furnace or lime kiln. The limiting lethal concentrations in aqueous effluent, as determined by Van Horn, et al., are from 0.5 to 1.0 ppm for H_2S and methyl mercaptan. As the condensates may contain as high as 50 ppm of these materials, it is sometimes necessary to pass the condensates through a desorber (Bergstrom) tower, where flue gases strip these volatile constituents from the aqueous phase.



This chart, drawn by the National Council for Stream Improvement, indicates the progress made by industry in water conservation.

In this way the condensate can be rendered safe for direct discharge into the receiving streams. (*7*) Figure 1 shows a graphic illustration of the average daily performance of a 400-ton unbleached linerboard pulping and recovery system. In another operation involving a 400-ton per day bleached Kraft market pulp, the performance figures are similar.

Neutral sulfite process and recovery

In the neutral sulfite system,* the wood chips are digested with a Na_2SO_3 solution containing a small amount of sodium carbonate or bicarbonate as a buffer to keep the pulping conditions just slightly alkaline. As large quantities of chemical (up to 50% of the weight of the wood) are required for complete chemical pulping, difficulties were encountered in maintaining efficient chemical recovery. For certain grades of paper and paperboard, particularly corrugating medium, hardwoods can be partially cooked with chemical dosages of 10 to 25% (dry wood basis) Na_2SO_3. Chips are digested at up to 180°C for two to three hours. The chips are then blown from the digester, and the softened chips and hot liquor are passed through disc refiners where a fibrous pulp mass is produced. After washing on multi-stage washers, a pulp yield of from 60 to 75% is obtained. With these high pulp yields, the amount of organic material in the spent liquor is considerably less than in the Kraft or sulfite process. Liquor concentrations amount to 6 to 9% total solids. In many of the original neutral sulfite installations, the economics were such that the spent liquors could be discharged to the sewer, but with the expansion of the industry, some method of chemical recovery is now imperative.

The burning of **soda-base sulfite spent liquors** presents some interesting problems in chemical equilibria. If the liquors are burned in a manner similar to Kraft recovery, the chemicals appear as a smelt in the form of carbonate and Na_2S. If the temperature is raised and an effort made to force the equilibrium toward conversion of S to SO_2, much of the Na is volatilized and lost in the flue gases. In the case of **magnesium-base liquors,** the furnaces can be operated at high enough temperatures to permit recovery of MgO as dust from the flue gases with the subsequent absorption of SO_2 in a magnesium oxide slurry. The difficulty with the burning of soda-base liquors is that the sulfur can appear as sulfide, as SO_2, and as SO_3 almost simultaneously. To effect a complete recovery the sulfides have to be recovered in the smelt and the SO_2 in the flue gases. The thermodynamics of the combustion of sodium-base pulping

* *This system was developed about 30 years ago by Bradley and McKeefe.*

liquors have been described *(9)*. Various schemes have been proposed for the burning of **neutral sulfite spent liquors** (NSSL) but most of these are based on the systems similar to the Kraft operation, in which the green liquor is reprocessed to convert the sulfide back to the sulfite for subsequent cooking.

Neutral sulfite semichemical processes

Three commercial processes *(10)* for NSSC recovery are reviewed here: In the **Mead process**, green liquor is treated with flue gases to carbonate the sodium salts and the liberated H_2S which is then burned to SO_2 and reabsorbed in the carbonate solution. In the proposed **Institute of Paper Chemistry process**, green liquor is treated directly with SO_2 gases which strip off the H_2S, which may be discharged through a stack or reburned for reuse. In both of these processes SO_2 and H_2S are together in a liquid or water vapor phase, and there is a strong tendency under these conditions to form sodium thiosulfate or free sulfur. In the **process proposed by the Western Precipitation Company**, some of the carbonate is crystallized from green liquor, and the sulfide-rich remaining green liquor is fed back to a furnace with incoming spent liquor. This forces most of the sulfur to appear as SO_2 in the stack gas and it may be recovered by scrubbing with carbonate solution. In forcing combustion reactions in favor of SO_2 formation in the flue gases, a heavy cyclic inorganic load is placed on the furnace and crystallizer. All three of these processes are now in commercial operation on a moderate scale and additional experience on these units will be necessary to resolve all the problems associated with this type of recovery.

Table 1. BOD loadings of various types of pulp mill processes*

COOKING RESIDUES

BASED ON UNBLEACHED PULP

TYPE COOK	YIELD RANGE	BOD RANGE LB/TON	TCOD RANGE LB/TON	TOTAL SOLIDS RANGE LB/TON
Neutral Sulfite	72 - 68	266 - 289	1025 - 1126	1100 - 1190
Acid Sulfite	47 - 40	670 - 833	3080 - 3695	2560 - 3260
Regular Kraft	42 - 38	860 - 1220	3860 - 5000	3640 - 5190
Prehydrolyzed Kraft	38 - 34	1220 - 1315	5680 - 6060	5150 - 5900

BLEACHING RESIDUES

BASED ON BLEACHED PULP

TYPE OF PULP	BLEACHED† YIELD			
Acid Sulfite				
- Paper Grade	93	29 - 37	152 - 175	266 - 346
- 90-91% Alpha	85	126 - 133	411 - 446	544 - 625
- 95% Alpha	70	169 - 210	536 - 685	760 - 870
Papermaking Kraft	88	20 - 44	120 - 335	470 - 634
Prehydrolyzed Kraft	92	19 - 33	136 - 145	368 - 463

* Unpublished Company Reports based on pilot plant cooks and bleaches of 100-150 lb. pulp batches wherein the entire washings could be quantitatively collected, sampled, and tested.

† Percent of unbleached pulp.

Many of the neutral sulfite semichemical operations produce a raw material for corrugating medium, and as the production of the medium is closely associated with Kraft linerboard production for corrugated shipping containers, many of the larger installations burn the liquor from the neutral sulfite operation along with the black liquor from Kraft pulping. The recovered Na_2S then is used as additional makeup chemical for the Kraft recovery, in place of using salt cake. On this basis, the Kraft recovery can absorb the sodium salts from the neutral sulfite operations in amounts equivalent to four or five tons of Kraft pulp production for every ton of neutral sulfite pulp produced. The spent liquor from the neutral sulfite operation is separated from the pulp by three or four stages of vacuum washing. The liquor then enters multi-effect evaporators separately, or with the Kraft black liquor. As the neutral-sulfite-operation raw material is predominantly hardwood, and as this is mechanically defibered before washing, its spent liquor contains a fair amount of fibrous fines which can cause considerable scaling and plugging of evaporator tubes.

An example of an actual operation combining Kraft and neutral sulfite recovery is shown schematically in Figure 2.

(Acid) sulfite process

In the acid sulfite process, the pulping reaction is carried out in large cylindrical steel digesters of 5,000 to 10,000 cu. ft. capacity. Most of the modern mills use the so-called *hot acid system* wherein the raw feed acid from the acid plant is increased in concentration and heated by the acid liquor from the pulping operation. A heavy concentration of SO_2 and steam circulates around the digester and hot-acid accumulating system. The acid contains an excess of from 3 to 9% H_2SO_3 above the concentration of bisulfite, and this excess acid has a vapor pressure above the normal saturated steam pressure. The pulping reaction involves both sulfonation and acid hydrolysis, and the excess acid increases the rate of reaction, and improves the liquor penetration into

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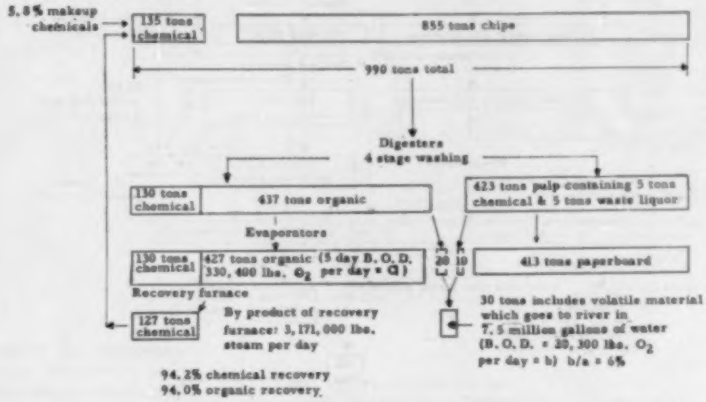

Figure 1. Unbleached kraft linerboard daily recovery performance.

Pulp and Paper

continued

the chips for uniform pulping. For practical purposes, only the amount of H_2SO_3 equivalent to the true bisulfite reacts with lignin, and an excess of acid equivalent to as much as five times the amount theoretically required for chemically dissolving the lignin, circulates between the digesters and the hot acid accumulator system. Under normal conditions, the liquor-to-wood ratio varies between 4½ to 5½ lb. of liquor/lb. of dry wood. With pulp yields at around 50%, this means that the dissolved organics in the liquids can reach concentrations of 10 to 12%. During the initial stages of cooking, a sizeable amount of liquid is withdrawn from the digester with the result that the concentration of organics in the remaining digester liquid can reach as much as 15 to 18% (a factor which is important costwise if evaporation of this liquor is to be undertaken). Toward the end of the digestion cycle there is a blowdown period wherein the pressures are reduced from a maximum of 90-125 to 30 lb./sq. in. or lower, and the remaining free gas, if any, is relieved to an acid accumulator system. The contents of the digester are then discharged into pits, where residual liquor is washed out by alternate flooding and draining.

Because of its low cost, calcium has been the base principally used in this pulping process. Other alkalis such as ammonium and sodium have solubility advantages but their additional cost must be justified by other factors, such as improved quality, capacity, or the ability to handle more-resistant wood species. In the recovery of chemicals and heat from the burning of spent sulfite liquor, there are many problems related to corrosion, scaling, and the recovery of chemicals in a form suited to cyclic re-use. The chemical reaction equilibria in calcium- and magnesium-base sulfite recovery systems have been analyzed and reported *(2)*, *(11)*. At the risk of oversimplification, the principal end-products resulting from the combustion of spent sulfite liquors at commercially feasible temperatures with different bases are listed in Table 2.

CO_2, N_2, and H_2O are present in all cases. It is seen that the calcium-base spent liquor produces $CaSO_4$, of no value for re-use. This fact, plus the

Table 2. Principal end-products resulting from combustion of spent sulfite liquors.

Base	End-Products
Calcium	$CaSO_4$
Magnesia	MgO, SO_2
Soda	Na_2S, Na_2CO_3
Ammonia	NO, SO_2

pronounced scaling tendencies of calcium liquors has slowed efforts to reclaim or dispose of these liquors by burning. On the other hand, the combustion of magnesia-base spent liquor at temperatures of 2400-2500°F produces end-products which are the very materials needed for preparation of pulping liquor. This has intensified efforts towards the development of the **magnesia-base process.** The first calcium-base mill was converted to magnesia-base in 1948; four mills are now in successful operation, including two new mills designed specifically for magnesia-base recovery. It appears feasible to recover approximately 85% of the pulping chemicals for re-use and to reduce the BOD loading on the receiving waterway by a like amount, as indicated by Figure 3.

The data shown in Figure 3 are typical of several months of operating experience at Weyerhaeuser's Grays Harbor Mill at Cosmopolis, Wash. This mill began operation early in 1957, with a rated capacity of 400 air-dry tons of standard bleached paper pulp per day. Its design was based on experience gained from extended operations with magnesia-base recovery systems at two other locations. Further improvements are being made. Data in Figure 3 were calculated on the basis that essentially all excess SO_2 charged to the digester, recycles as vent gas back into the cooking acid for successive cooks, and that the bisulfites and sulfates charged to the digester appear in the spent sulfite liquor.

Net steam production, generated at 850 lb./sq. in. ga. (825°F), amounts to 7,500 lb./air-dry ton of bleached pulp, over and above the quantities required for evaporation of the weak, spent sulfite liquor, and for other internal operations of the recovery system. Thus the magnesia-base recovery system offers not only a means of disposal, but also a means of utilization, of the residual organic matter.

Though more completely covered elsewhere *(12)*, *(13)*, the recovery system for the magnesia-base process is of sufficient commercial importance to merit a brief description of one of the newer installations. The pulp mass, after dumping the digester, is washed on four countercurrent stages of drum type vacuum washers, with clean hot water added to the last stage. Weak liquor from the washers, with 12-13% solids, is concentrated to 50-55% solids in a seven-body, sextuple-effect counterflow evaporator, equipped with two spare bodies to facilitate cleaning. The heating elements are vertical-tube, single-pass, forced-circulation heat exchangers, evacuated by a surface condenser with noncondensable vapor ejectors. Construction is solid stainless steel, Types 317 and 316. Rated capacity is 246,000 lb./hr. The feed liquor is partially neutralized by addition of $Mg(OH)_2$ slurry, just ahead of the evaporator.

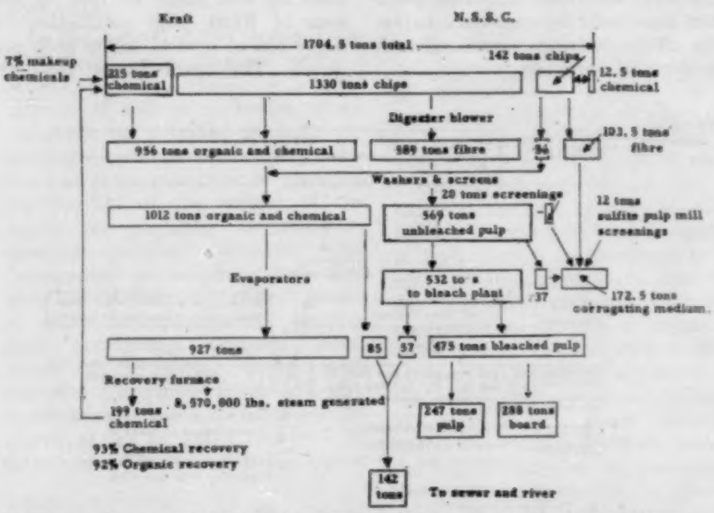

Figure 2. Bleached kraft and neutral sulfite semi-chemical operations—daily.

Table 3. Typical BOD Balance Standard Bleached Sulfite Pulp Production at Grays Harbor Mill*.

Source	Flow million gal./day	BOD ppm	BOD lb./day	BOD lb./air-dry ton
Recovery sewer	0.8	5400	36,000	90
Bleach plant sewer	14.0	103	12,000	30
Pulping group sewer	0.8	300	2,000	5
Screen room sewer	3.4	212	6,000	15
Combined sour sewer	19.0	354	56,000	140

*Based on 360 tons/d. of moisture-free bleached pulp (equivalent to 400 tons/d. on conventional A.D. or air-dry basis).

Concentrated liquor at 50-55% solids is quite viscous and shows some tendency to polymerize. There is also some danger of scale formation because of silica and calcium, which originates in the wood chips and builds up in the recycled liquor. Hot-end evaporator effects are periodically switched out of service for washing with condensate, to control the calcium scaling problem. A semi-annual wash with caustic soda eliminates the silica scaling problem.

Concentrated liquor from the evaporators, at about 260°F, is pumped to pressurized storage tanks, which are maintained at the same pressure as the vapor of the final liquor-concentrating evaporator effect, and to the burner nozzles of the two recovery furnaces.

The recovery furnaces are specially designed to maintain a combustion zone temperature of 2400-2500°F. With preheated combustion air regulated to give 2-2.5% excess oxygen, and steam atomization of liquor at the burner nozzles, the combustion of the concentrated liquor is essentially 100% complete, with formation of a finely divided open-structured MgO ash. There are negligible quantities of carbon and carbon monoxide present. Sulfur compounds produced, are principally SO_2, with small amounts of SO_3. The furnace, boiler, superheater, and gas air heater are laid out in such fashion as to keep the MgO ash in suspension until it can be separated from the gas stream by Multiclones. The separated dry ash is washed with water to remove soluble impurities, then slaked with hot water to $Mg(OH)_2$, prior to the acid-making step. Small amounts of commercial $Mg(OH)_2$ slurry are added as makeup at this point.

After the MgO ash is separated from the flue gas, the gas is cooled from about 400°F down to approximately 100°F by direct contact with water sprays in packed towers. The collected water is passed through heat exchangers to warm the process water, and recycled to retain absorbed chemicals. The cooled gases, containing about 1% SO_2, along with tail gas from the acid storage tanks, are passed through a series of three packed towers, where the SO_2 is absorbed. Makeup water is added to the last (dilute) tower and $Mg(OH)_2$ slurry to each tower. Acid is circulated in each tower at a high rate, and transferred countercurrent to gas flow, from the last tower toward the first, at system rate. Acid is drawn off the first (strong) tower at system rate to a settling tank and then to sand filters for removal of insoluble impurities (principally $CaSO_4$ and silica). After fortification in contact (under pressure) with high concentrations of SO_2 from makeup burner gas and digester venting, the acid-bisulfite liquor is ready for use in digestion.

Table 3 shows a typical BOD balance for the production of standard bleached paper pulp at the Grays Harbor Mill. BOD values for specialty pulps tend to be higher than those shown. Values for a separate sewer system which collects mill waters low in BOD and which has no connection with the recovery system are excluded from Table 3. This separate "sweet" sewer collects filter plant backwash water, hydraulic log barker effluent, and excess waters from the bleached pulp screens and pulp drying machine. It has a flow of about 6 to 7 million gal./day and a BOD loading of approximately 7 to 10 lb./ton of pulp.

The importance of the recovery is seen in Table 3. The BOD loading in this sewer comes principally from the evaporator condensates, from occasional entrainment problems in the evaporators, and from washings from evaporator effects and strong liquor tanks. The presence of volatile organics in the evaporator condensates has been demonstrated. Some of these volatile organics are acidic and are rendered non-volatile when the evaporator feed liquor is partially neutralized with $Mg(OH)_2$; which also reduces losses of small quantities of feed-liquor SO_2, to condensates. Table 4 shows data for BOD acidity, and pH of evaporator-combined condensates during experimental runs in which the feed liquor was adjusted to a series of pH values by addition of $Mg(OH)_2$ slurry. The evaporator operation was allowed to stabilize for several hours at each condition before samples were taken.

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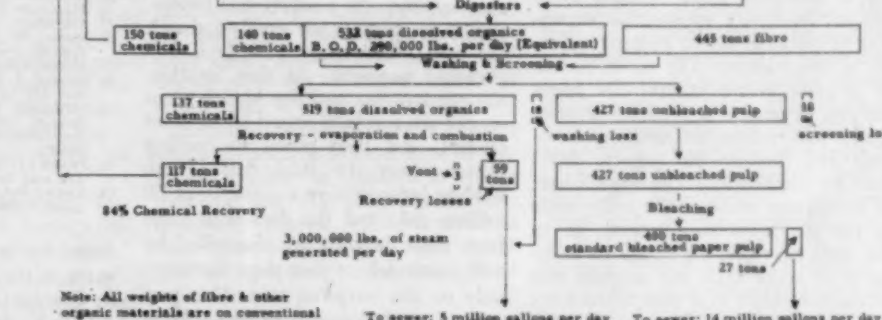

Figure 3. Magnesia base recovery performance—standard bleached sulfite paper pulp.

Pulp and Paper

continued

It is to be emphasized that in the standard method used for determining BOD values, oxygen-demand of the SO_2 present is not reported as BOD, but rather as immediate-dissolved-oxygen-demand, or IDOD, *(14)*.

Table 4. Effect of feed-liquor pH on evaporator condensate properties.

Feed-Liquor				
pH	3.5	4.4	5.5	5.9
Combined Condensate:				
pH	1.8	1.8	2.3	2.2
Acidity, as				
% SO_2...	0.38	0.29	0.13	0.11
BOD, ppm	4600	4700	3200	2000

A number of **ammonium-base sulfite-mill** operations have resulted from conversion from use of calcium (on the basis that certain pulp qualities are improved) or that a wider variety of woods can be pulped. Like magnesium-base and sodium-base, ammonium-base spent liquors present no appreciable scaling difficulties, and so can be evaporated and burned, but as yet, no practical means has been devised for recovery of ammonium-base pulping chemicals. Until this can be accomplished the ammonium-base process offers little promise as an economic solution to the waste disposal problem.

Soda-base process. Pilot plant work is progressing toward an economically feasible means of preparing sulfite pulping liquor from the products of combustion of its spent liquor. If and when this recovery process proves to be successful, another feasible means of recovery, and consequent reduction of BOD load will have been effected.

Of approximately 60 sulfite pulp mills in the United States, all but a few are more than 20 years old. All but four (to the best of our knowledge) are using either the calcium-base process or the ammonium-base process for which, as mentioned earlier, there is no practical recovery system. Because of limitations of supply of desirable wood species, there has not been any appreciable expansion of the acid sulfite pulping industry in this country. The surest means of in-plant waste control for spent pulping liquors is a recovery system which will reclaim the cooking chemicals and destroy the organic BOD load by combustion. The capital cost of converting some of the older mills to the magnesia-base process, or to the soda-base process would in many cases be more than the original cost of the mill, built at a time when costs were much lower. Thus the decision to convert is not easily made.

Additional treatments and special effluent handling methods

In recent years, some progress has been made in applying biological treatment methods to pulp and paper mill wastes, in a manner similar to the practice for municipal wastes. West Virginia Pulp and Paper Co. has installed a large activated-sludge treatment unit at their plant at Covington, Va. *(15)*. This plant has a capacity for treating over 16 million gal./day and embodies: primary settling, a mixing box for nutrient feeds and activated sludge, aeration, and final settling. Effluents to be treated are carefully selected and premixed to obtain the proper pH for optimum BOD removal. On a BOD basis, the plant treats 70% of the mill wastes, and removes 75 to 80% of the BOD in the wastes treated. This amounts to reducing the total mill pollution to the river by more than 50%. In suspended solids removal, the plant has an efficiency of 85 to 90%. This reduces the total mill-suspended solids to the river by better than 75%. The plant has a total solids removal efficiency of about 30% and a BOD removal efficiency of 35% *(15)*.

Another approach to biological treatment consists in holding the effluents for long periods of time in very shallow lagoons. Many of the mills of the southern part of the United States use waste swamp lands and sloughs for this purpose. Some of these systems cover areas of many acres with travel lengths of 7 to 20 miles. National Container Corp. operates such a system at their plant at Valdosta, Ga. (16). To render these systems effective, the effluents within the plant must be carefully controlled in proportion, to obtain effective natural bio-oxidation.

The Everett bleached Kraft plant of Weyerhaeuser is located on the main channel of the Snohomish River which (in turn) is near to the shores of Puget Sound. The flow of the channel supports a substantial fishery, and its capacity is too small to absorb the mill effluents even with a 94% chemical recovery. At this location, the condensates and the bleach plant wastes are carefully mixed by in-plant control, and then piped to holding lagoons near the tidal flats. These holding lagoons have a capacity of 50 million gal., and the discharge gates from these lagoons are controlled by mill personnel, so that they discharge only on the outgoing tide. This permits a rapid dispersal of the effluent with the bay water and prevents backing-up of the effluent into the river during the incoming tide. A similar installation has been made at the new magnesium-base sulfite plant at Cosmopolis, Washington, which is located on Grays Harbor. Here also, condensates and bleach plant effluents are mixed and piped 2½ miles to the holding ponds on the tide flats well into the mouth of the Grays Harbor estuary. The gates of these holding ponds are remotely controlled to discharge only on the outgoing tide.

ACKNOWLEDGMENTS

The conservation and scientific management of our natural resources are a primary concern of the Forest Products Industry. In recent decades, great strides have been made in managing timber as a crop, to provide trees and wood products for the future. Forest lands, as tree farms, are part of the drainage areas forming the genesis of our water resources; the proper protection and use of forests and water are a basic concern of the Pulp and Paper Industry. Efforts by individual companies, and combined talents working through associations like the APPA, the National Council for Stream Improvement, the Northwest Pulp and Paper Association, and others, have the common objective of protecting our water resources by pollution abatement and proper water management.

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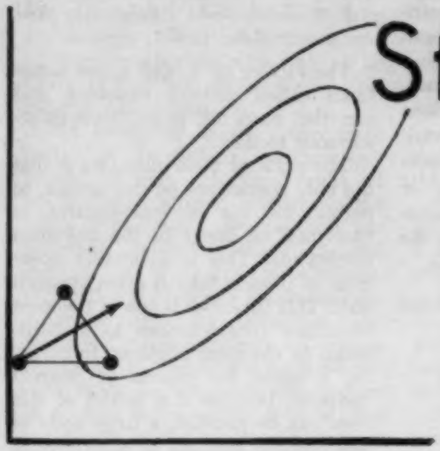

Statistics in the strategy of chemical experimentation

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THE AIM OF most chemical investigations is to predict the behavior of a process or the properties of a product. An effective experiment is one which results in the broadest possible reliable predictions from a specified amount of experimental effort. To obtain effective prediction from chemical experimentation, full use should be made of modern statistical methods to complement, not replace, engineering and chemical principles.

As noted by G. E. P. Box, the strategy of experimentation is an iterative process beginning with a theory (or model) of a system which is the basis for an experiment. This experiment suggests a new model which in turn leads to another experiment, etc. The engineer should select the appropriate model at each stage. The statistician should schedule or "design" the experiment to discriminate among alternative models and to predict precisely with the selected model. The engineer and statistician should combine engineering intuition and statistical inference in the analysis of the results.

The important distinguishing features of an experimental strategy incorporating statistical methods are:

1. The model takes account of both known chemical mechanisms and random phenomena in the experiment.
2. The scheduling of data collection commands the same expert attention as chemical and engineering theory and laboratory technique.
3. The inferences drawn include some measure of imprecision.

To consider the normal sequence in an experimental program, the researcher must have some theory about the mechanism of the system under study.

In the case of quantitative investigations, a mathematical model is used, however crude, which the experiment is to confirm, reject, or modify. This model may involve only an intent to plot yield against temperature, on some scale to be determined after the data are collected. This intent implies that there exists some function, $y = f(t)$ which will be useful for predicting yield. The researcher must then schedule experiments, and decide what set of experiments will relate yield to temperature.

The initial schedule may involve a single experiment to determine whether any product is obtained at all, or may be an elaborate statistically-designed program. The experiment must then be performed with attention to equipment, analytical procedures, etc.

Some inferences must be made from a numerical analysis of these data. The engineer must decide whether the data confirm or contradict his model; whether the model is adequate or needs refinement; whether the model permits interpolation, extrapolation, or neither. Further, he needs some measure of the reliability of his predictions.

The analysis suggests a model which then becomes the basis for a second set of experiments and the cycle is repeated.

After trying several such cycles (or iterations) involving a sequence of models and experiments, an *adequate* model is derived which is then the basis for making the final predictions or decisions. The steps of this developmental sequence are shown in Figure 1.

Although this introduction may be considered a statement of the obvious, it is the relationship of the engineer and statistician in each of these steps which is crucial in the proper strategy of experimental work. The construction of equipment and refinement of experimental technique have been the stock and trade of many industrial chemists and chemical engineers. Their tools for the construction of a model, have included such varied theoretical and empirical devices as reaction kinetics, theory of heat transfer, and log-log graph paper, while

continued

for the scheduling of experiments, intuition has been the rule. In the final step, analysis and inference, the methods and concepts of modern numerical analysis and statistical inference have, at best, only recently been made an appendage to the engineer's education.

The tools of the statistician, in guiding the course of experimental work up until 1950, consisted primarily of: analysis-of-variance and first-order regression, for models; factorial and fractional-factorial designs, and the principle of "blocking," for scheduling experiments; and confidence-intervals and hypothesis-testing, for analysis and inference. A comparison of these two lists of tools of the engineer and statistician gives some

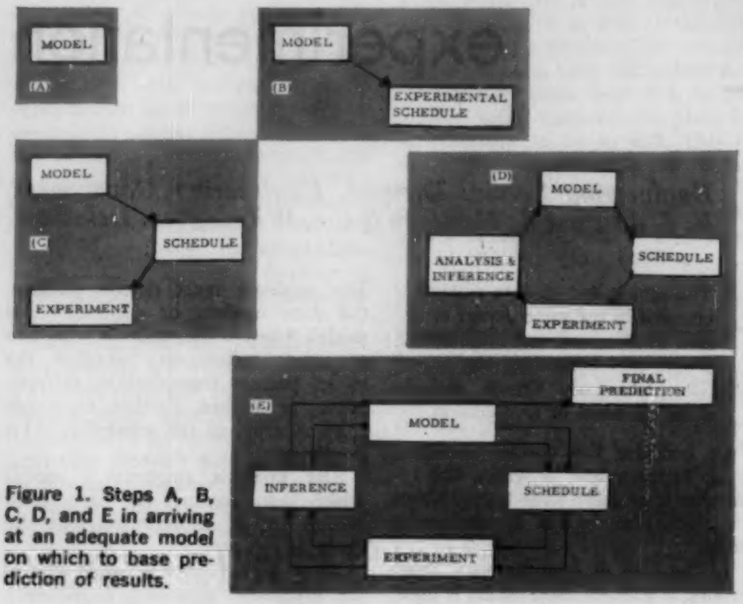

Figure 1. Steps A, B, C, D, and E in arriving at an adequate model on which to base prediction of results.

indication of why these two groups did not join forces to solve the experimental problems of the chemical industry sooner.

Two bench marks in the development of statistical theory, which strongly influenced all available methods, are:

1. Theory of least-squares, due to Gauss (1796)
2. *Design of Agricultural Experiments,* a basic text by R. A. Fisher (1935)

The theory of least-squares provides procedures for obtaining *best* estimates for unknown coefficients from experimental data, where the model whose constants to be estimated are of the form:

$$y_i = \beta_0 + \beta_1 z_{1i} + \beta_2 z_{2i} + \dots + \beta_k z_{ki} + \epsilon_i \qquad (1)$$

where:

y_i = observed value of response (dependent variable) for i-th experiment

β = unknown constants to be estimated

z = factors (independent variables) observed without error in the experiment

ϵ = independent random normal variable with mean zero and unknown variance, σ^2. This term represents all the sources of experimental and measurement error inherent in the experimental procedure.

The point to note is the flexible nature of the factors, z. In one experiment we may have

$$z_1 = \frac{x_1}{x_2} = \frac{\text{feed rate}}{\text{reactor volume}}$$

$$z_2 = log(x_1 x_2)$$

$$z_3 = x_1^{2.3}$$

which, on substitution of terms yields the model:

$$y = \beta_0 + \beta_1 \frac{x_1}{x_2} + \beta_2 log(x_1 x_2) + \beta_3 x_1^{2.3} \qquad (2)$$

In another case we may have

z_1 = 1, for reaction using no catalyst;
= 0 otherwise.

z_2 = 1, for reaction using fixed catalyst bed;
= 0 otherwise.

z_3 = 1, for reaction using fluidized catalyst bed;
= 0 otherwise.

z_4 = temperature, °C.

giving the model:

$$y = \beta_0 + \beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3 + \beta_4 z_4 \qquad (3)$$

The factors z_1, z_2 and z_3 are sometimes called *dummy variables,* and are the basis of many analysis-of-variance models.

The point of these examples is that the only restrictions on the models, to permit the use of least-squares, is that they be linear in the *unknown* coefficients. This is a broader spectrum of models than is often appreciated. This flexibility is one of the most important considerations to a statistician or chemical engineer formulating a model for process or product behavior, because if a model of this form can be justified, a large body of well codified methods of experimental design and analysis may be used.

The second important bench mark in statistics is the work of Sir Ronald Fisher. He wrote his classical book, *The Design of Experiments* (*1*) as a result of assisting agricultural research workers at Rothamsted Experimental Station. From his work, and those who followed in his footsteps, several basic habits were established which still influence statisticians' ways of thinking about experimentation. His formulation of models, designs and methods of statistical inference were naturally influenced by the field in which he was working. A large number of the experiments performed at the agricultural research stations were screening tests. The problem was to test large numbers of new varieties of crops, to screen for new types with improved yields, or disease resistance, on land with much variability in fertility. To describe these results, the classical analysis-of-variance model was postulated:

$$y_{ij} = \mu + t_i + b_j + \epsilon_{ij} \qquad (4)$$

where:

y_{ij} = yields using the i-th treatment or variety on the j-th block or plot

μ = average yield

t_i = deviation of average yield obtained on i-th variety from average yield over all variety

b_j = deviation of average yield obtained on j-th plot from average yield over all plots

ϵ_{ij} = random variation from experiment to experiment.

An elaborate statistical methodology, *analysis-of-variance,* was built on this

simple model and its variations, which fall into the class of linear models suggested by Gauss. However, as the methods were refined, much use was made of the methods where this model was inappropriate to describe the experiment. The habit of *arguing by analogy* from one experimental situation to another, with little or no study of the underlying model, became common practice.

We have now built a rather large body of statistical methodology around a very restricted class of mathematical models, and are in the habit of planning only one large experiment, collecting the data, and making a final recommendation. While this is clearly a generalization, it sheds light on difficulties encountered when engineers and statisticians try to understand each others' viewpoints. In retrospect, one feature of all this development is clear, the statistician tended to play an increasingly dominant role in the decisions regarding the mathematical model, the scheduling of the experiments, and the conclusions to be drawn from them. To be sure, the experienced consulting statistician studied the particular experiment to be planned, but having once familiarized himself with the necessary background, he (more or less) took over the reins, except for the laboratory work itself, till the interpretation of the results was turned over to the research worker.

In such an experimental program a few years ago, a group of engineers had been guided in their planning by this sort of statistical thinking. About half way through the completion of the laboratory work, the statistician was transferred. The engineer continued the schedule which had been set forth for him, but as the completion date neared he was more and more concerned about the analysis of his data. He had only a rather vague idea of what questions were to be answered by this analysis, though by this time he had obtained some reference material indicating the proper arithmetic operations to be performed in the analysis. The design was sufficiently intricate so that intuition was of little help in interpreting the data.

Clearly, any strategy which relegates the chemist or engineer to such a secondary role in the abstracting, scheduling, and interpreting of an experiment must be ineffective and frustrating to the experimenter concerned. He must feel that he has relinquished his proper role—as in truth he has.

Beginning with the paper by Box and Wilson (2) of the models, design and inference of statistical methodology have been rapidly modified to meet the needs of chemical experimentation.

The basic unifying concept which is emerging from the statistical research of Dr. George Box and his co-workers is that of research as an **Iterative Process.** This concept has radically modified the way statisticians think about statistical models, techniques of scheduling or designing experiments, and the type of inference required at the completion of a phase of laboratory work. The concept of iteration is not new to laboratory research—but the statistician's awareness of this inherent feature of experimentation is leading to a great modification of statistical methodology. The sequence of model (or theory) schedule, experiment, and inference involves several cycles, or iterations. These iterations may be divided arbitrarily into three general phases: qualitative, quantitative-empirical, quantitative-theoretical, Figure 2.

In the first phase the experimenter is concerned with finding a synthesis, screening for the important environmental variables influencing the reaction yields and product properties, and obtaining a general qualitative understanding of *how* the system behaves. In the second phase, he attempts to determine how good a product can be made and at what cost. This requires quantitative-empirical information concerning the effects of temperature, catalyst concentration, and similar environmental factors. Finally, he wants to know *why* the process and product behave as they do; that is, the mechanisms governing the system. The understanding of the reaction kinetics and mechanisms governing a process permits us to predict its behavior over a much broader range of conditions, and therefore to consider a much wider spectrum of methods of manufacturing the product. However, many plants have been operating profitably for years with only a limited understanding of "what is going on inside the kettle." Most current statistical methods are primarily applicable to the second phase, though new techniques are being developed which will be helpful in the theoretical phase. Due to the complexity of many chemical processes, a large amount of experimental work is carried out in phase two before a theoretical understanding can be reached.

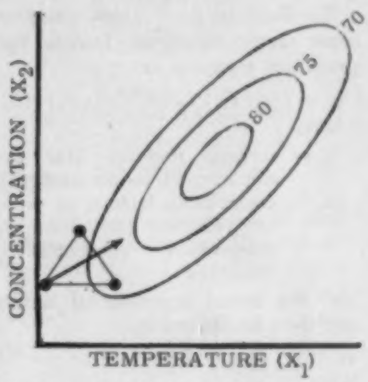

Figure 3. Two factor contour diagram.

The quantitative-empirical stage can be subdivided into three steps. In the first step an attempt is made to bracket the *feasible economic range*

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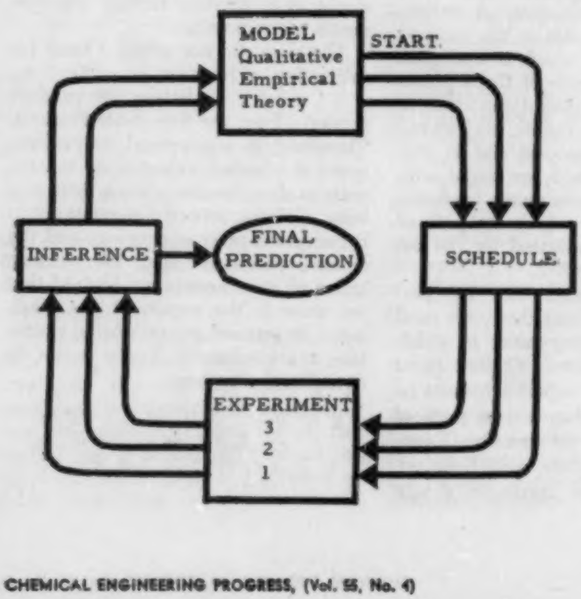


Figure 2. Three phases of iterative process.

Statistics

continued

of the environmental variables which determine the yield of the process and the properties of the product. Of assistance in this step is the statistical method of *steepest ascent*. The second step describes the locus of economic operating conditions, that is; it seeks a description of *how* the process behaves in the region of economic interest so that an optimum set of conditions may be selected. An important facility in this step is *Box's method of surface fitting*. The third step looks for clues to the basic mechanism of the process from the empirical relationships determined in step two. One technique that has been developed, to lead from an empirical understanding to theory, is *canonical analysis of quadratic response functions*.

To illustrate these ideas, consider some simple examples. Denote the prediction equation as:

$$\eta = f(x_1, x_2, \ldots, x_i, \ldots, x_k) \quad (5)$$

where:

η = average response (for example; yield, tensile strength)

x_i = controllable factors, or process variables (for example; temperature, concentration, cycle time)

and the actual experimental results can then be defined by

$$y_j = \eta + \epsilon_j \quad (j = 1, 2, \ldots, N)$$

where:

y_j = value of response for j-th experiment

ϵ_j = random experimental variability associated with j-th experiment. This is a normal random variable with *mean zero* and *variance* σ^2

The purpose of the N experiments is to define the function well enough to answer such questions as:

(1.) What are the conditions (values of x) for maximum yield?

(2.) What is the *order* of the chemical reaction?

(3.) What are the conditions for maximum tensile strength with acceptable aesthetic properties of the product?

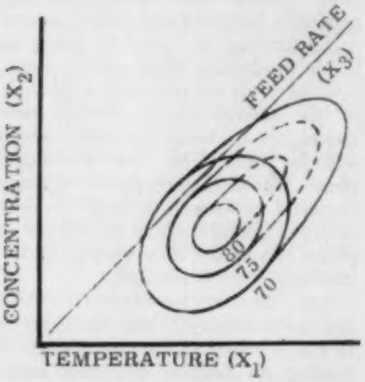


Figure 4. Three factor contour diagram.

To visualize the problem it is convenient to represent the function graphically. Thus, draw contour diagrams showing loci of constant response, y. Figure 3 shows loci of constant yield in the (two-factor) temperature-concentration plane. Adding a third factor (feed rate) these loci become contour surfaces such as those shown in Figure 4. The locus of constant response thus becomes a surface in three-dimensional space.

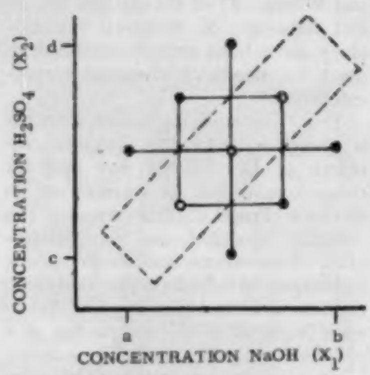


Figure 5. Partial plan of proposed experiments.

The first step in the quantitative phase of a research problem is the location of the general region of interest in the *factor space*. A statistical technique for this is the method of steepest ascent, which is analogous to noting the altitude of three points on the side of a mountain, fitting a plane to the three points, and noting the *direction* of steepest rise in that plane. Using Figure 3, we might arbitrarily select the three points (defining the triangle) from which the path of steepest ascent, indicated by the arrow, may be computed.

Single experiments can be performed at steps along this path until the predicted improvement in yields is no longer obtained. At that point another pattern of experiments can be performed indicating a new path of steepest ascent. If the function (Equation 5) is reasonably well behaved, a region near the maximum should

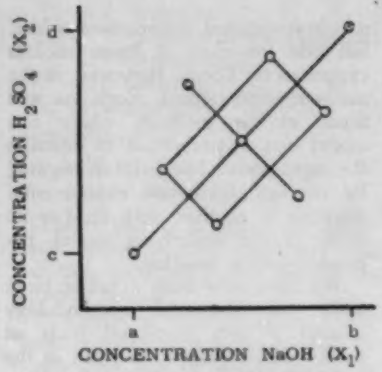


Figure 6. New coordinates for design.

finally be reached, which could be explored more exhaustively. Having arrived in a near-maximum region, we are now ready to make the first iteration on our model. In this phase of the investigation we have postulated a *first-order model*,

$$\eta = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_k x_k \quad (6)$$

using the appropriate first-order designs, (3), to schedule the experiments.

The following example should serve to illustrate the use of statistical methods to explore the behavior of a system near the maximum response. By varying the concentrations of five constituents, it was desired to improve one key property of a product which had been made by a particular process for several years. In this program each experiment was planned after looking at the results of a previous experiment. A sequence of more than one hundred such experiments was performed, where judgement was the sole guide for selecting combinations of the five factors. Although some improvement was attained, there was doubt as to whether further improvements were possible,

The data did not afford a basis for estimating a function $y = f(x_1, x_2, \ldots, x_5)$ for predicting the product property from the five concentrations. Therefore, it was agreed to perform a set of planned experiments to estimate such a function. Since little was known of the theoretical relationship between the product property and the concentrations, and since the previous series of experiments established that we were in the region of the maximum, it seemed reasonable to postulate a *second-order* Taylor series to describe the system:

$$y = \beta_0 + \beta_1 x_1 + \ldots + \beta_5 x_5 + \beta_{11} x_1^2 + \ldots + \beta_{55} x_5^2 + \beta_{12} x_1 x_2 + \ldots + \beta_{45} x_4 x_5 + \epsilon \quad (7)$$

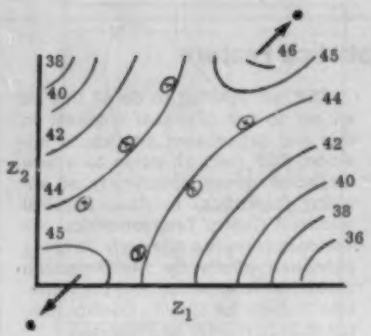


Figure 7. Contours of constant product property.

A rotatable composite design, *(4)* consisting of 27 experiments, was proposed. To use this design it was only necessary to specify: the factors, the range over which they were to be varied, and the scale of measurement to be used for each. After the chemist specified these, the statistician produced a schedule of experiments. The chemist indicated that several of these were impossible because no product could be produced under some of the combinations of concentrations in the schedule.

Two of the factors appeared to be in dispute so a plot (Figure 5) was made of these. When the proposed experiments were plotted, the chemist indicated that six of the nine combinations (solid dots) were certain to yield a poor product, if any at all, but he maintained that the concentration ranges were correct.

The region of interest was established as the rectangle included in the dotted lines. The problem was then to determine how to use the efficient symmetrical rotatable designs within this sort of restriction.

By adopting the new coordinates;

$$\begin{aligned} z_1 &= x_1 + x_2 \\ z_2 &= x_1 - x_2 \\ z_3 &= x_3 \\ z_4 &= x_4 \\ z_5 &= x_5 \end{aligned} \tag{8}$$

and selecting the proper ranges for z_1 and z_2, these same experiments were plotted in the z_1z_2 plane in the region shown in Figure 6. The general problem of spanning the correct region of factor-space* is an extremely important concept. See footnote in column two.

Continuing with our example; the data were collected and the 21 constants in the second-degree polynomial were estimated. By computing the 90%-confidence limits for all the coefficients, it was found that all coefficients related to x_4 and x_5 were so small that their confidence limits bracketed zero. Therefore, it was decided to use a third model, to predict the product property:

$$y = \beta_0 + \beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3 + \beta_{11} z_1^2 + \ldots + \beta_{23} z_2 z_3 + \epsilon \tag{10}$$

To indicate the type of conclusions drawn from the analysis by the chemist, consider a two-factor cross-section of the three-factor response surface, Figure 7. Inspection of the graph suggests that we can obtain a *high value* of the property in a region running diagonally from the lower left to the upper right corner of the factor-space; that extrapolating the contour of the saddle point in the directions of the arrows would lead to an even higher value of the property. Therefore, eight

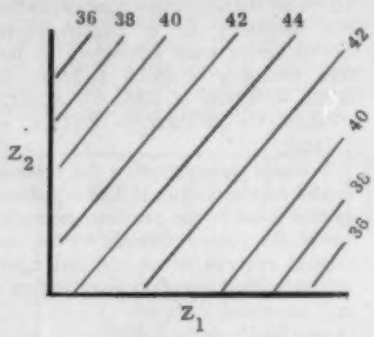


Figure 8. Contours of canonical equation for product property.

additional experiments were performed; six confirmed the existence of a region with high values of the product property. However, at the two extrapolated points (solid dots), the property remained at 44 rather than giving the predicted higher value of 48.

While the confirming experiments were being performed, the quadratic

* *Where more than two factors are involved in the transformations, graphical methods are of little help in suggesting the correct new variables. However, the symptom of a poor model, namely the resulting illogical or unfeasible experiments obtained from symmetrical designs, is usually corrected when one tries to express the factors in more fundamental terms. One interesting feature is that transformations of the factors such as:*

$$\begin{aligned} z_1 &= x_1/x_2 \\ z_2 &= \log x_1 \\ z_3 &= e^{-(x_1 + x_2)} \end{aligned} \tag{9}$$

suggested by theoretical considerations as being "more fundamental" quantities in the system, tend automatically to solve the problem of spanning the proper region of factor-space.

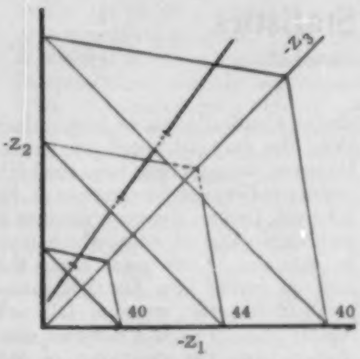


Figure 9. Contours of product property.

form of Equation (10) was reduced to its canonical form:

$$y - 43.9 = -2.61v_1^2 - 0.43v_2^2 + 0.29v_3^2 \tag{11}$$

where:

$$\begin{aligned} v_1 &= -0.746(z_1 - 0.388) + 0.428(z_2 + 0.232) - 0.510(z_3 - 0.024) \\ v_2 &= -0.526(z_1 - 0.388) + 0.019(z_2 + 0.232) + 0.850(z_3 - 0.024) \\ v_3 &= 0.250(z_1 - 0.388) + 0.891(z_2 + 0.232) + 0.379(z_3 - 0.024) \end{aligned}$$

From the relative magnitude of these coefficients and the fact that the coefficients of v_2^2 and v_3^2 are not signifi-

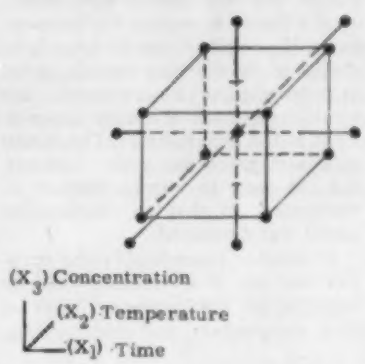


Figure 10. Three-dimensional configuration of "central composite design."

cant, it seems reasonable to consider the simplified model:

$$y = 43.9 - 2.61v_1^2 \tag{12}$$

A two-factor cross-section of these contour surfaces at $z_3 = 0$ is shown in Figure 8.

Comparing the contours in the z_1, z_2 plane, Figures 7 and 8, see an

continued

almost identical locus of high values along the diagonal noted previously. However, we no longer have the high values predicted at the extremes of the diagonal. Rather, Figure 8 predicts a maximum value of 43.9, which may be obtained at any point along the line, no matter how far it is extrapolated. But the response falls off rapidly to v_1. This is a different conclusion from the viewpoint of the chemist. There now exists a locus of good operating conditions, but no place where we may expect an improved product.

Figure 9 shows the three-factor contours of Equation (12). There is a planar locus of *maximum response*, with all the variation in response ocurring in a single dimension; the vector perpendicular to the optimum plane, passing diagonally through the system. This suggests the conclusion that there are not five factors governing the response, but rather a single basic factor; some function of x_1, x_2 and x_3 which completely determines the properties of the product. This conclusion should not be surprising since we are not measuring fundamental quantities here, but readily measurable concentrations.

It would have been desirable to pursue this *clue* and to have developed a theory to explain this phenomenon. If correct, it would have been similar to the first two models, as far as interpolation is concerned, but would have made a further improvement in the extrapolation. The results at this stage of the study, however, did not seem to warrant further investigation, so that no fundamental model was developed.

In another example (*5*) the problem was one of maximizing yield by selection of the *optimum levels* of time, temperature, and concentration.

Special CEP Statistics Feature

This is the first in a special series of articles to appear in CEP over the coming months on the subject of statistics as applied to chemical engineering. Many new statistical techniques are useful in engineering, new applications of older techniques are being found each year, often many methods can be applied to a particular job, and the engineer needs to know which to employ.

CEP will attempt to do all this as an aid to the chemical engineer in this and subsequent articles. In addition, CEP calls attention to a new magazine aimed specifically at applying statistics in the physical sciences. Called, Technometrics, the new magazine is a quarterly, is being published jointly by the American Statistical Association and the American Society for Quality Control. Editor is J. S. Hunter of Princeton.

The data were collected in a design similar to the previous example, but in a three dimensional configuration; a "central composite design", Figure 10. From these fifteen experiments the ten constants in a second-degree Taylor series were estimated, as before, giving $y = 58.78 + 1.90x_1 + 0.97x_2 + 1.06x_3 - 1.88x_1^2 - 0.95x_2^2 - 0.69x_3^2 - 2.71x_1x_2 - 2.17x_1x_3 - 1.24x_2x_3$

Without demonstrating the contour model corresponding to this equation, as was done in the previous example, we shall proceed directly to the canonical analysis which resulted again in a simplified equation involving only one canonical variable:

$$y - 59.15 = -3.40z^2$$

where:

$$z = 0.75x_1 + 0.48x_2 + 0.45x_3 - 0.35$$

The predicted yields of this equation can be represented by a contour surface similar to the second model for the previous experiment and is shown in Figure 11, where a plan of maximum yield of 60% passes diagonally through the system, with planes of lesser yield on either side. (This was as far as the analysis proceeded in the previous experiment.) The problem was then considered from a more fundamental point of view. The differential equations were then written defining two first-order reactions for the formation of product and by-product. The temperature-dependence of the rate constants was described by the standard Arrhenius equation. After estimating the constants in these equations from the same data, we could again deduce the yield-surface in the same three-dimensional factor-space, Figure 12.

Note the similarity between the empirical and theoretical contours. They both demonstrate that there is a whole *surface* of maximum yield, rather than a single point of maximum yield.

A third example, a kinetic study by P. H. Pinchbeck (*6*), illustrates another use of empirical functions to study chemical systems.

From an initial study incorporating five factors, three functions of these factors were considered to be of primary importance in characterizing the system. With some consideration of the appropriate scale of measurement, the model, $y = 234_1 + 151x_1 + 259x_2 + 310x_3 - 20x_1^2 - 60x_2^2 - 73x_3^2 - 51x_1x_2 - 71x_1x_3 - 143x_2x_3$

where: y = mole conversion

x_1 = log contact time

x_2 = log (air/naphthalene ratio)

x_3 = temperature

was fitted to the data.

The conversion contour surface is very nearly a set of concentric cylin-

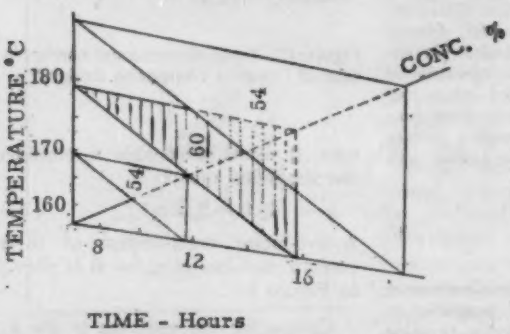


Figure 11. Contours of empirical yield surface with sections at three levels of concentration.

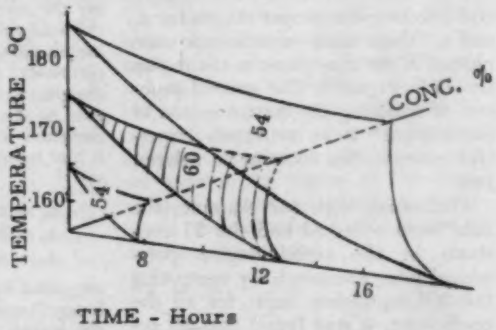


Figure 12. Contours of theoret. yield surface with sections at three levels of conc. independent of temp.

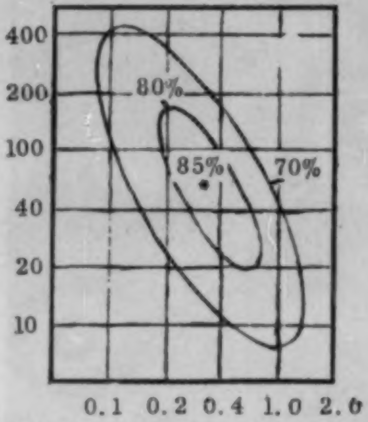
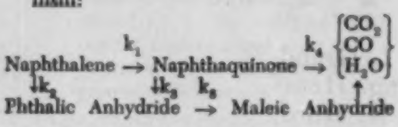


Figure 13. Contours of conversion based on empirical equation.

ders, a two-factor cross-section of which is shown in Figure 13.

Pinchbeck postulates the mechanism:



This sequence of five reactions represents only the qualitative aspects of the mechanism. To write the equations for predicting the behavior of the system we must further postulate the *order* of these reactions. The three most likely hypotheses were:

1. Disappearance of naphthalene, half-order; subseq. steps, first order.
2. All steps first order.
3. Disappearance of naphthalene, second order; subseq. steps, first order.

Integrating the rate equations implied by these three hypotheses, we can deduce for each case the conversion as a function of the feed-ratio and time, Figure 14. It is easily seen that the first hypothesis (Case 1) is the only one which implies a set of conversion contours compatible with the empirical investigation summarized in Figure 13. Therefore this mechanism was selected.

Pinchbeck concludes, "The investigation demonstrates that the purely empirical approach, when treated systematically, can throw considerable light on the basic mechanism of the reaction under investigation and provides a new approach to complex multi-variable reactions."

In all the examples cited, the functions estimated from the experimental data have been linear in the unknown constants. In many situations these linear models are not adequate. In these cases it is necessary to use the recently-developed methods of *non-linear estimation*. One excellent example of this technique is a paper by Box and Coutie *(7)* where a set of four differential equations was postulated to describe the reaction kinetics in which it was required to estimate two rate constants. From the experimental data, a joint-confidence region for the two constants was estimated. Because the computations involved in a problem of this type are considerably more complex than conventional linear estimation, a computer is of great assistance.

The two difficulties inherent in non-linear methods are the considerable increase in computation over linear regression, and the lack of efficient experimental designs for these models. The first difficulty is readily overcome with the aid of modern computers, especially if good programs are already available for the computer to be used. The second difficulty is somewhat greater, but with the great interest in this subject, non-linear designs should be available in the very near future. To counterbalance these disadvantages, non-linear models describe a much broader range of chemical systems with enough precision to permit extrapolation and interpolation. It permits the engineer and chemist more opportunity to make use of their theoretical knowledge of the system in postulating an adequate model.

With the flexibility of linear-regression models, and the large number of efficient first- and second-order designs, there should seldom be an experimental situation for which the postulating of a model will not aid in efficient experimental work. With the increasing number of methods for gleaning clues from linear models concerning more fundamental relationships, these should be excellent stepping stones for understanding the underlying mechanisms of systems for those cases where the empirical model is not considered adequate. When non-linear methods are added to this array, the pattern of "iterative" experimental strategy should become a sequence of orderly efficient experiments, where the engineer or chemist makes use of all available theory at each step of the program. *"Whatever is selected by the scientist as a basis for quantitative measurement depends upon his intellectual ability in perceiving the important characteristics of a given experience and in making hypotheses and conceptual theories relating these characteristics to others that can be tested by future experiment." Statisticians must not substitute as a basis for quantitative measurement, (in statistical jargon, "design of experiments") a blind adherence to elaborate statistical schemes such as latin squares, composite rotatable designs, and the like. These tools are extremely useful, but they are not the basis of conceptual thinking about the system under study. This basis must be supplied by the chemist or engineer conducting the investigation. To capitalize on his knowledge of the system, the engineer must seek the new methods which specify efficient designs for, and pertinent analysis of, data at each step of his experimental program. He must use the science of experimental strategy, ***statistics***, which is more powerful than experience and intuition in obtaining a high yield of pertinent information from engineering principles and experimental budgets.

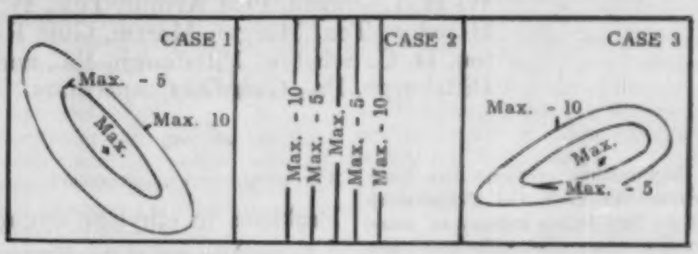


Figure 14. Contours of theoretical conversion.

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* *W. A. Shewhart (8), Bell Telephone Laboratories, one of the first industrial statisticians.*

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Distribution and storage of ethylene

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A high-quality ethylene has been marketed by Gulf Oil Corporation from its Port Arthur refinery for more than five years. Two ethylene units are now in operation, producing a total of over one million pounds per day. These two units, while not identical in size or detailed design, both employ the general process flow shown in Figure 1. Refinery gases are fed into the compression section where they meet gases coming from the pyrolysis furnaces. After compression to suitable pressures, the mixed gases then enter the recovery system, where the products shown are segregated. Feed to the pyrolysis furnaces consists of (1) ethane recovered in the ethylene units and (2) propane and occasionally butane recovered from other refinery operations. When required, propane is also obtained from outside sources.

Gulf ethylene is delivered by 147 miles of pipeline to a number of industrial customers within a radius of roughly 75 miles. Ethylene leaves the recovery section as a liquid at −25°F. It is pumped through a vaporizer and a superheater, and enters the pipeline as a gas at a pressure of about 600 lb./sq. in. gauge. It reaches metering stations at pressures ranging downward from about 500 lb./sq.in. gauge, depending on the distance from the ethylene plant and the rate at which it is being taken by customers.

Problems in ethylene storage

To meet the goal of providing continuous and dependable service (*1*), a means of storing a sizable quantity of ethylene was needed. In the chemical industries, inventories equivalent to a production of 20, 30, or even 60 days are not uncommon. When the product is a gas, however, storage of large quantities becomes a problem. Gulf's pipeline provides some storage capacity in itself; but, this is not enough to accommodate a major difference between production and consumption rates for more than a day or two. Total capacity of the line, after all, is only about 964,000 lb. ethylene at 600 lb./sq. in. gauge, or less than one day's production. Even this much is not actually available, however. In order to maintain the minimum pressures guaranteed to the customers, the average line pressure must be held above 300 lb./sq. in. gauge, at which pressure about 400,000 lb. ethylene still remain in the line. Thus the surge capacity of the line is equivalent to less than half a day's production.

What was needed was storage for quantities of the order of 30 million pounds or more. Several possible methods presented themselves:

1. Store it at low temperatures in steel vessels as a liquid.
2. Store it like "town gas" in large gasholders at essentially atmospheric pressure.
3. Store it at high pressure in steel vessels as a gas.

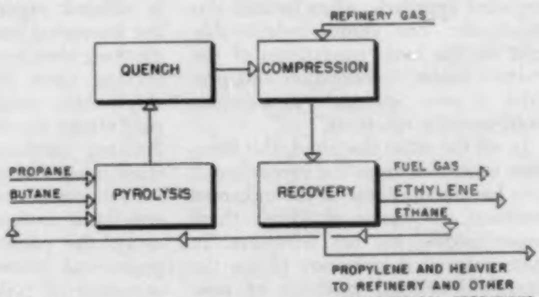


Figure 1. Both Gulf units, while not identical in size or design, employ this general process flow sheet.

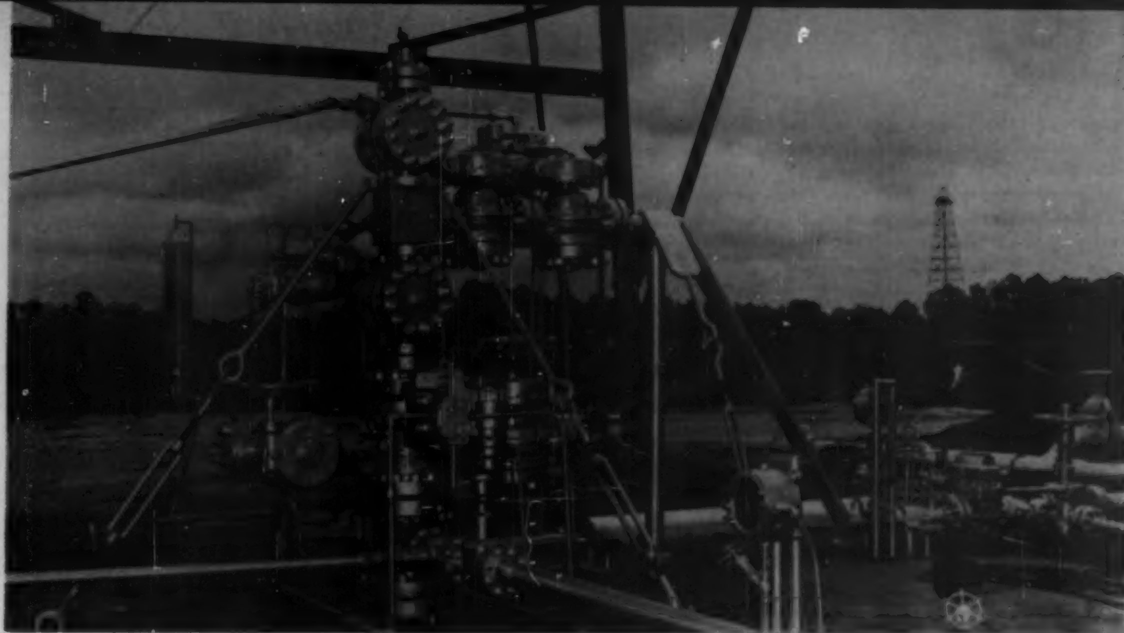


Figure 5. This view shows the wellhead equipment, valve operators, and pressure sensing safety equipment. Ethyleneline in foreground.

4. Store it like natural gas in depleted oil or gas wells or other porous underground strata.
5. Store it in cavities in underground salt deposits.

The critical temperature of ethylene is about 50°F., and the critical pressure is 748 lb./sq. in. abs., Figure 2. (It is convenient to remember 50°F. and 50 atm.) Therefore, it can not be stored as a liquid without some cooling. Even at −40°F. the vapor pressure is still up around 200 lb./sq. in. To store liquid ethylene at atmospheric pressure, it must be maintained below −150°F. This is not impossible. One is aware of the work that has been done and is being done in the storage and transportation of liquefied natural gas at −260°F. But that technique is not inexpensive, either.

Ethylene has a specific volume of about 14 cu. ft./lb. at atmospheric pressure and 75°F. For a plant producing well over a million pounds of ethylene per day, provision for any useful amount of surge capacity in gaseous form, not to mention inventory storage, becomes a major problem. A 15-million cubic foot gas holder (about as large as it is practical to build) would store approximately one day's production.

The density of gaseous ethylene increases rapidly, of course, with increased pressure, especially above the critical pressure. Densities approaching liquid density (15-20 lb./cu. ft.) are possible at normal temperatures if the pressure is raised to around 2,000 lb./sq. in. This is the pressure in ordinary gas cylinders—nitrogen cylinders, for example—that are used in small-scale applications. But the amount of ethylene that could be handled in such containers would be insignificant in comparison with the planned scale of operation.

As for storage in depleted gas or oil sands, it seems likely that enough residual gas would be present to contaminate the high-purity ethylene severely. The advantage of the storage would be largely lost if it were necessary to repurify the ethylene before it went into the pipeline.

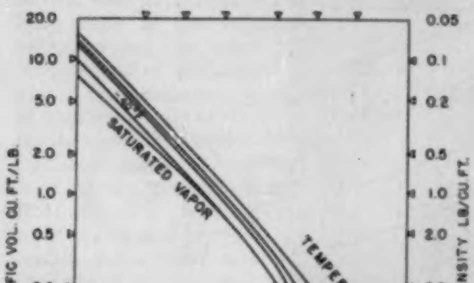


Figure 2. Ethylene PVT diagram. Note that ethylene cannot be stored as a liquid without some cooling.

Underground salt deposits

Recovery of salt from underground deposits has been carried on for many years, either by mining or by pumping down water to dissolve the salt and pumping out the brine.

Although the idea of using underground cavities in salt deposits for storage had been developed long before, it was not until 1950 that it found large-scale commercial application for storage of petroleum products. However, the practice met a need and was so successful that it expanded at an incredible rate. When the problem of storing ethylene arose in 1953, some salt cavity storage had been developed in New Mexico and preparations were being made to leach out a cavity in a salt dome near Fannett, Texas, about 20 miles west of Port Arthur, for storage of liquefied petroleum gas. The ethylene pipeline passed within two miles of the Fannett dome. Storage of ethylene in the Fannett dome thus presented an interesting possibility.

Underground deposits of salt are found in many parts of the United States. In the Gulf Coast area—East Texas, Louisiana, and Mississippi—the salt has been thrust upward by geologic action in many places into great underground salt domes. Some of the

continued

domes in the area are of the "deep-seated" type, lying farther beneath the surface. The Fannett dome is a "piercement-type" structure, that is, it has broken through some of the overlying strata and has driven relatively close to the surface. (See Figure 3). The domes are, of course, highly irregular in shape, having followed the lines of least resistance in their upward thrust.

These domes have been of interest in the past not only for their salt content, but also because of the fact that the irregular rock structures around their sides have tended to trap many pockets of gas and oil. At the Fannett dome, Gulf Oil Corporation is the major operator, producing oil and gas from ninety-six wells around the sides of the dome. In the process of drilling in this field, an area of about 360 acres has been outlined where salt is encountered at 2000 to 3000 ft.

Table 1. Pressure, Temperature Gradients in Underground Cavities, Interface depth—3400 feet.

Depth ft.	Brine p lb./sq. in. gauge	Ethylene p lb./sq. in. gauge	Temperature °F.
0	0	1340	
500	260	1408	85
1000	520	1472	98
1500	780	1534	105
2000	1040	1595	109
2500	1300	1657	113
3000	1560	1718	116
3400	1768	1768	118

As has been stated, the storage of LPG in salt cavities was a well-established practice in 1953. After some consideration of the technical problems which might be peculiar to ethylene storage, it was concluded that ethylene could be similarly stored. Ethylene will not liquefy at the temperatures prevailing underground, but pressures of 1000 to 2000 lb./sq. in. can easily be held in the salt cavities, giving an ethylene density approaching liquid density. No contamination of the ethylene is possible since hundreds of feet of inert salt separate the ethylene from the natural gas outside the dome.

Gulf now has four storage wells in the Fannett dome—two for ethylene, one for propane, and one for butane. These wells are placed near the center of the dome where the top of the salt is about 2000 to 2200 ft. below the surface. Each well is about 1000 ft. long and of 5 to 80 ft. diam., with the tops of the wells about 2900 ft. below the surface. Selection of these particular depths was somewhat arbitrary but was guided by the following considerations:

A. The ethylene is stored over saturated brine. As the ethylene is pressured into the cavity, brine is displaced through a long tube reaching to the bottom of the cavity and is collected in large gunite-lined pits up on the surface. When ethylene is withdrawn, brine from the pits flows back into the well. The well should be deep enough so that the static head of brine will maintain a fairly high pressure on the ethylene.

B. On the other hand, too deep a hole will require too much pressure to charge the ethylene into the cavity against the head of brine.

C. A long, narrow hole will permit more accurate measurement of the interior and thus better estimation of the volume of ethylene in the cavity.

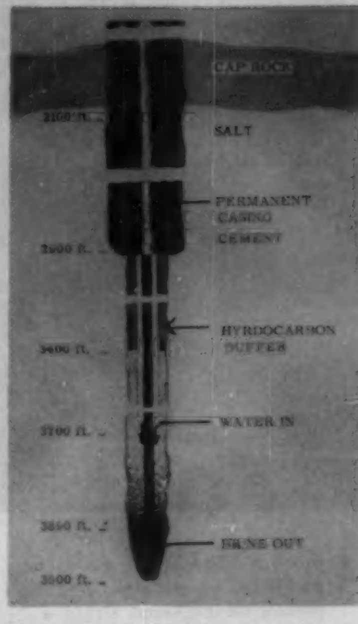


Figure 4. Details of leaching string.

Preparing the cavities

Preparation of a salt dome cavity starts off much like oil well drilling. A drilling derrick is set up at the desired site, and a hole is drilled down through the overburden and into the salt. Steel casing is cemented in place down to the 2900-ft. level, which is intended to be the top of the cavity. Drilling is then continued another 1000 ft. down through the salt. The well is then ready for leaching.

Various leaching programs may be used, but the following is a typical example: with the drilling completed, concentric tubes of 7 and 3-½-in.

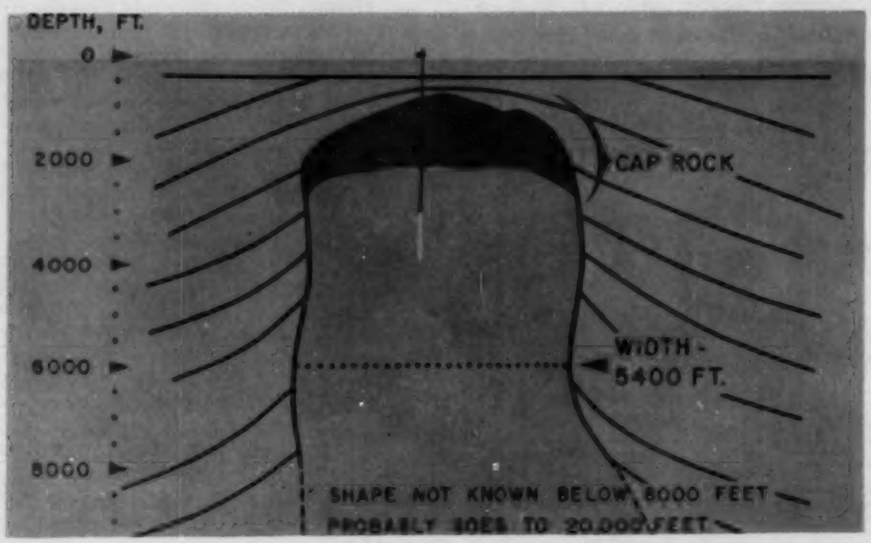


Figure 3. Cross-sectional view of the Fannett Salt Dome looking southwest.

O. D. are run into the hole for the leaching operation (Figure 4). The 3-½-in. pipe is initially set 10 to 12 ft. off the bottom of the hole, and the 7-in. pipe is held 150 to 250 ft. from the bottom. Water is pumped in through the annulus between the 7- and 3-½-in. pipes, with brine being taken off through the 3-½-in. pipe. Flow in the opposite direction can also be used, but it has been found that the method described gives 10% faster leaching. In addition, insoluble anhydrite crystals (anhydrous calcium sulfate), which make up 10-15% of the salt deposit, are more effectively removed through the smaller tube.

The water used for leaching is largely "field water"—a dilute brine (about 6% NaCl) produced along with the oil from the wells in the area. About 7000 to 8000 bbl./day of this water is available in the Fannett area. It is supplemented with up to 2000 bbl./day of fresh water from a bayou that passes nearby. The water is circulated at a pressure of 600 lb./sq. in. by a centrifugal pump. Brine leaving the well is passed to an earthen pit to allow anhydrite or other solids to settle out, and is then pumped down one of the disposal wells normally used for disposing of field water. These wells are drilled down to a porous formation which, at Fannett, appears to have almost an unlimited capacity for water. The presence of such a formation is quite fortunate. Although the need for a means of disposing of brine may not be as apparent a requirement for creating a cavity of this type as the need for a salt formation or a water source, it can easily be a determining factor.

During leaching operations, careful measurement of flow and of the salt concentration in the water in and out of the well is maintained so as to keep track of the volume of void being created. In order to prevent leaching out of salt around the lower end of the permanent casing, the top of the cavity—down to about 3,400 ft.—is kept filled with a light hydrocarbon material. Thus little or no leaching is accomplished in this section. In early leaching operations, some raising and lowering of the concentric tubes were done to control the form of the hole, and the leaching strings were withdrawn from time to time to permit use of logging devices for determining the size and shape of the cavity. It is now generally considered desirable to leave the leaching strings in one position for the entire operation.

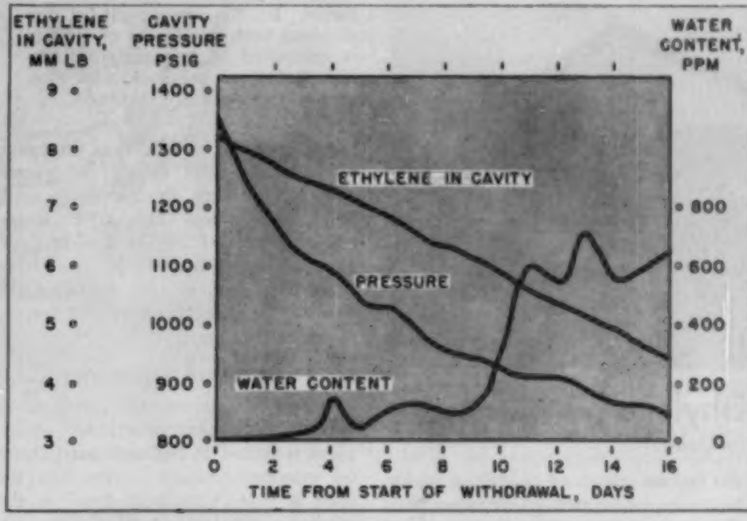


Figure 6. Test run of ethylene withdrawal from underground storage.

Under the conditions described, about 700 to 1000 bbl. of void space per day is created, or about one barrel of void for every 8.5 bbl. of water circulated. Thus, a 150,000-bbl. cavity requires about six months to leach out after drilling is completed. At present, there is in excess of 400,000 bbl. (30,000,000 lb.) of ethylene storage capacity at Fannet.

When the leaching operation is completed, as determined by the amount of salt which is calculated to have been removed, a caustic solution is circulated for a day or two to neutralize any hydrogen sulfide present on the walls of the salt cavity. The leaching strings are then removed and a Dowell sonar log of the cavity is run to determine its size and shape for calibration purposes.

Ethylene storage in salt cavities

The dipleg provided to carry brine into and out of the cavity is a tube of about 5-in. diameter reaching to within about 75 ft. of the bottom. Around that is a concentric tube of about 7-in. diameter ending about 30 ft. higher. The dual brine string is important, not only in providing a spare in case of a leak or a plug in the inner tube, but also to serve a warning function. The presence of ethylene or an increase in pressure at the top of the outer tube (normally closed) indicates that the cavity is overfilled with ethylene to the extent that the surface of the brine is below the end of that tube. With only one tube,

Figure 7. These ethylene dehydrators are piped in parallel, each having the capacity of 30,000 lb./hr. throughput.

Figure 8. The movement of the ethylene both in and out of storage is controlled at this metering station. Well-head pressure, flow rate, and temperature are recorded.

Ethylene

continued

the first indication of overfilling would be an explosive flow of ethylene from the open brine tube. As an added precaution against this danger, all brine is returned to the storage pits through a flare tank placed in the center of the largest pit, which is 350 ft. wide by 750 ft. long.

Ethylene is stored in these cavities under the pressure exerted by the head of brine in the brine tube, which is approximately 0.52 lb./sq. in. for every foot of head. If the interface is 3400 ft. down, the pressure on the ethylene at that level is about 1768 lb./sq. in. gauge (See Table 1). Ethylene pressure at the surface is less by the amount of the head of ethylene. This head will vary, depending upon the quantity stored and the temperature in the cavity, but is usually of the order of 0.11-0.14 lb./sq. in. gauge/ft. of head. (Ethylene density of 16-19 lb./cu. ft.) This puts the ethylene pressure at the well-head in the range of 1200 to 1500 lb./sq. in. gauge. The temperature in the cavity will level off at about 115-120°F. if the cavity is closed off for a few days. Rapid transfer of ethylene to or from the cavity will, of course, affect the temperature and therefore the density of the ethylene.

Above-ground equipment

Figure 5 shows the complex of valves and pressure-sensing equipment required at the well-head above an ethylene storage cavity. At the base of the "Christmas tree" is the ethylene line coming from the pipeline; above that, valves for the outer brine line; next, the main brine attachment; and at the top, a valve for introducing fresh water to flush crystalline salt formations out of the brine lines when necessary.

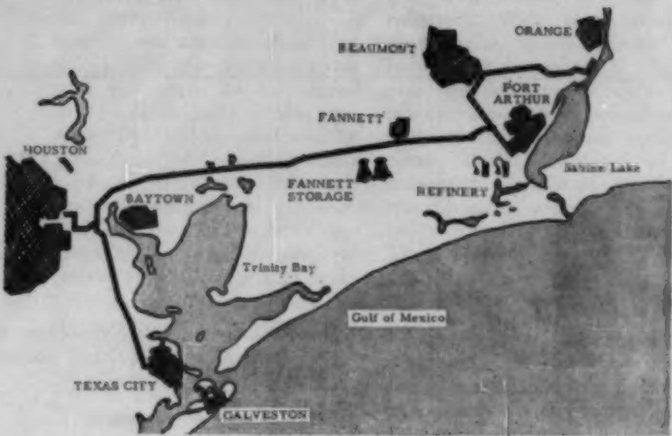
Two gas-engine driven reciprocating compressors, one of 350 and the other of 400 bhp., have been installed at Fannett to charge ethylene to the cavities. These compressors take ethylene from the pipeline at 500-600 lb./sq. in. gauge, and, as shown previously, work against a well-head pressure of 1200 to 1500 lb./sq. in gauge. Total capacity of the two machines is roughly 900,000 lb./day, which is sufficient to handle any foreseeable production surplus.

Ethylene leaving the storage cavities will have varying water content, depending on how full the well is and how fast the gas is withdrawn. Over a depth of 3000 ft. or more there is some stratification of gas composition. An early test of the capabilities of well No. 1 showed this up very well as shown in Figure 6. The first gas coming out had a low water content, but as the gas was drawn off at a rapid rate over a period of more than two weeks, the water content finally rose to about 500 p.p.m. In later tests as much as 1200 to 1600 p.p.m. has been encountered.

In order to reduce the water content of the ethylene leaving the cavities to specification levels, it is, therefore, necessary to provide dehydration equipment (Figure 7). Expansion of the ethylene from storage pressure to line pressure cools it substantially. Half of two-thirds of the water content can thus be eliminated by flashing the ethylene into knock-out drums. The gas then passes through beds of solid adsorbent, which reduce the water content to 0.1 to 4.0 p.p.m. Ethylene can be withdrawn from storage through the dehydrators at a rate of about 1,000,000 lb./day, with two desiccant towers handling ethylene and two being regenerated.

Hot natural gas is used for regeneration of the adsorbent. Regeneration with dry ethylene from the pipeline has been considered. However, there has been some concern over the possibility of ethylene polymerization in contact with alumina under these conditions. No evidence has been observed that such polymerization would actually take place, but regeneration with natural gas is simple

Figure 9. Aerial view of the Fannett underground storage facilities. Reading clockwise around the larger reservoir, beginning at the lower left hand corner, the wells are 4, 1, 2, and 3.



Fgure 10. Map of the ethylene pipeline systems used by Gulf.

and effective and has therefore been continued.

The quantity of ethylene going into or coming out of the storage cavities is calculated on the basis of readings made with orifice-type meters. Figure 8 is a photograph of a typical metering station. Similar meter stations, set up just inside the property line of each customer, are constructed and operated in accord with defined principles (2).

Commercial ethylene contains small but measurable quantities of ethane, methane, hydrogen, carbon dioxide, and acetylene. To the extent necessary to assure accuracy, therefore, properties of the actual gas mixture rather than of pure ethylene are used in calculating flow rates from meter readings. For the gases present in minor quantities, previously published supercompressibility data have been assumed to be sufficiently accurate for use in these calculations; but for ethylene itself, experimental supercompressibility data were developed (3).

Metering the ethylene into and out of storage provides a close day-to-day estimate of current inventory. This is checked periodically by actual measurement of interface depth in the cavities. Loss of ethylene from the entire storage and distribution system is so small that it can not be determined with any certainty. Any difference between ethylene production and consumption, as measured by the metering equipment at various points in the system, is assumed to represent loss, but this loss has averaged less than 0.5% of the ethylene handled.

Figure 9 is an over-all view of the storage area at Fannett, showing the brine storage pits, the derricks over the wells, and the control house. The metering, compression, and dehydration equipment are off to the left, out of view.

Gulf ethylene pipeline

The Gulf ethylene pipeline, is made up of about 147 miles of 6- and 8-in. pipe reaching westward to Houston and Texas City and north to Beaumont and Orange from the refinery at Port Arthur (Figure 10). Ethylene is received by approximately ten customers along the line at widely varying rates, and successful operation of the system requires close coordination of production, storage, and distribution.

The whole pipeline system is controlled by a central dispatcher in Houston. The dispatcher is in contact with all customers, the producing units at Port Arthur, and the operator of the Fannet storage area by means of a leased wire telephone system. All of these, of course, operate on a 24-hr. day basis. The dispatcher receives readings of line pressure and flow rate at each of these points every two hours.

When ethylene is being produced at Port Arthur faster than it is being taken by the customers, pressure in the pipeline will rise. This rise is not abrupt, since there is some surge capacity in the pipeline itself. With production exceeding consumption by 100,000 lb./day, it would take over two days for the pressure to build up from 500 to 600 lb./sq. in. gauge. When the line pressure at Fannett goes above 580 lb./sq. in. gauge, the dispatcher instructs the operator at Fannett to begin putting ethylene into storage and to continue doing so until the pressure has been reduced to 500 lb./sq. in. gauge, at which time the dispatcher advises the operator to shut down the compressor.

When the refinery is not producing enough ethylene to meet demand, ethylene is metered out of storage, usually at a rate equal to about one-half the rate of total customer take. It can, of course, be withdrawn at a faster rate if necessary. Normally the operator is told to begin withdrawing ethylene from storage when line pressure drops to 475 lb./sq. in. gauge, and to stop when the line pressure is up to 550 lb./sq. in. gauge at Fannett.

Underground storage of ethylene is by far the most inexpensive way to maintain a large inventory of this gaseous commodity. Really the only other storage method at all practical for any appreciable quantity of ethylene is low-temperature-liquid storage, and investment for such storage may run many times the cost of salt cavity storage. In addition, low-temperature-liquid storage suffers from high operating costs because of continuous operation of the refrigeration equipment.

The incorporation of salt cavity storage facilities into the Gulf ethylene system has proved highly satisfactory. In addition to the ethylene storage, the storage of propane and butane at Fannett introduces still more flexibility to the system. These materials can be returned to the ethylene plants and cracked to make ethylene if normal refinery sources are interrupted. This storage installation made it possible to maintain a high load factor in ethylene sales and to meet high peak loads. It provides the flexibility of inventory which is necessary in any manufacturing operation. There is no contamination of the high-purity product in storage, except with water, which is readily removed at high throughput rates by simple solid adsorbent dehydrators. Both investment and operating costs are relatively low.

ACKNOWLEDGMENT

Acknowledgment is due the various departments of Gulf, specifically, the Production Department, Manufacturing, and the Transportation Department (Gulf Refining) for the installation and operation of the pipeline system.

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Presented at A.I.Ch.E. Meeting, Salt Lake City, Utah

Solar space cooling

Design considerations and test results to provide a nominal cooling capacity during a normal eight-hour working day using energy supplied by a solar source.

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The relation between space-cooling demands and solar energy supply in areas of high solar radiation suggested the possibility of solar operation of absorption-cooling systems. In climates where space heating is needed, the same solar energy collector may be used for both winter heating and summer cooling. The flat-plate collectors suitable for use, however, have outputs which vary with time and intensity of incident solar radiation; therefore, direct substitution of the flat-plate solar collector for a conventional energy source for an absorption cooler is not feasible.

The costs of cooling by solar energy (5) are not now competitive with the costs of cooling by conventional means in temperate climates. However, for the cost/ton-hr. of cooling to be competitive with conventional systems, it was estimated that for coolers combined with solar heating systems it should cost no more than $2-7/sq. ft. of solar collector and its associated cooling system. Research and development on coolers and collectors should produce equipment costs within the allowable range. The allowable cost depends on the local price of energy from conventional sources, the equipment use factor, and the annual fixed charges. Thus, it appears that there could be combined operations of heating and cooling which would be competitive with conventional systems *in areas of high energy costs* in the near future. Solar cooling alone may be competitive in some foreign areas of large cooling demands and high-cost energy.

* *Löf (1) has described a dehumidification system in which cool triethylene glycol is used to absorb moisture from air to be conditioned; this moisture is then stripped from the glycol by solar-heated air. Intermittent absorption-cooling units regenerated by solar energy (for small food refrigerators) have been discussed by Williams, et al (2), and cycles of this type can (in principle) be applied to space cooling. It is also possible (in principle) to operate compression refrigeration systems by solar-generated mechanical energy. Solar operation of absorption ice-producing equipment has been described by Trombe and Foex (3) and by Kirpichev and Baum (4).*

Solar cooling systems

Solar air-conditioners (or coolers) of several types* have been proposed. The type of continuous cycle described here, Figure 1, operates with steady flow of refrigerant through the components of the unit whenever heat is supplied from a solar collector, storage, or an auxiliary source. Other modifications of the collector or cooler may be used. The collector may serve as a refrigerant generator, or, the generator may be heated indirectly. The combination of generator and collector has the advantages of both reducing equipment requirement, and reducing the overall drop in temperature between the collector absorbing surface and the refrigerant-absorbent mixture in the generator.

Indirect heating of the generator makes it possible to interpose an energy storage unit between the collector and generator, allows more flexibility of operation of the collector, and permits easier use of the collector for winter space-heating operation. Indirect heating seems to be necessary if organic refrigerants or absorbents are used, because the equilibrium temperature of the absorbing surface in a well-designed collector, during periods of *no heat removal* from the collector, can be high enough (400-500°F) to cause decomposition of organic materials.

Energy storage, or thermal inertia, can be added to the system in several ways.

1. It can be interposed between the collector and generator in an indirectly heated system (hot-side storage) thereby smoothing out the energy supply to the generator, and permitting operation of the cooling system at, or near, design rates during periods of reduced radiation. The disadvantages of this are an increased temperature difference between the collector and

generator, and heat loss from the storage unit.

2. Storage in another fluid (or solid) between the evaporator and the space to be cooled (cold-side storage) is also possible. This arrangement has the advantage of requiring only moderate temperature difference between storage and ambient. "Losses" to storage from the space to be cooled are not real losses if the storage unit is in that space, and the capacity requirements (Btu) are less* than for hot-side storage by a factor of the †*coefficient of performance* of the cooler.
3. It should be possible, in principle, to store liquid refrigerant; but the quantities required are large compared to the normal amount of refrigerant needed in the system.
4. Thermal inertia in the building can provide some storage.

Most previous studies of solar refrigeration used movable focusing reflectors. With clear skies, these produced a nearly-constant energy-output rate throughout the day. However, well designed flat-plate collectors can operate in the temperature ranges required for absorption cooler generators. Their advantages of simpler construction, and suitability for use in space heating, indicate their potential utility for solar cooling applications.

The absorption cooler. The design of the solar-heated absorption cooler is basically the same as that for cooling systems heated by fuels, but modified by the particular requirements and limitations imposed by the variable solar-energy source. In order that a satisfactory *solar collector performance coefficient* (Energy transferred to heated fluid or to the generator/unit of incident solar energy) can be achieved, collector temperatures must be moderate, and heat transfer surface in the cooling unit must be designed for operation at temperature differences less than conventionally used. Cost considerations are affected by the nature of the operation. The addition of heat exchanger area to increase the cooler COP may be considerably cheaper than adding additional collector area to achieve the same increase in output. Selection of an absorbent-refrigerant system must be based on obtaining maximum COP with comparatively low generator temperatures necessitated by the conditions for efficient solar collector operation.

Design of a solar cooler

The solar cooler has been designed to provide cooling in part of a laboratory building in regular daily use through normal working hours, until about 5:00 p.m. An average cooling load of 8000 Btu/hr. through an 8-hr. working day, or 64,000 Btu/day, has been established as the design load. *Design* weather conditions were taken as average August, clear-day solar radiation for Madison, Wisconsin, and 90°F ambient temperature. Thus, the solar cooler must be capable of operating at a steady rate of 8000 Btu/hr. (with hot-side storage), or at a variable rate up to approximately 1.5 times the nominal rate to produce an average of 8000 Btu/hr. (with cold-side storage). The temperatures in the absorber and condenser are fixed at 100°F by the maximum temperature of the cooling water available. The collector is most easily designed as a multiple of a basic unit size (fixed for this study at about 21 square feet). The units have copper sheets with integral tubes for water, coated with a selective black surface and covered with two or three layers of glass. Five of these units having a total area of 107 sq. ft. and tilted 35° to the south should provide sufficient energy (when storage is used) to operate the cooling unit at design capacity for the day. Collector performance calculations are based on the methods of Hottel and Woertz (*6*).

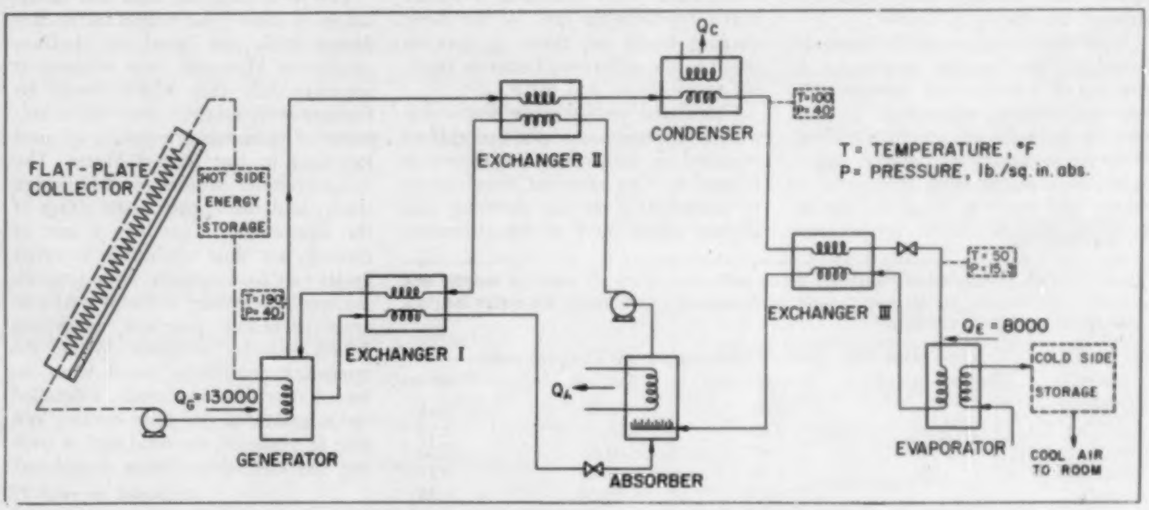
Figure 1 shows the principal temperatures and pressures for the unit operating at the nominal cooling capacity of 8000 Btu/hr. The generator and evaporator temperatures are based on compromises between good performance of the cooler (requiring high temperatures) and good performance of the solar heat exchanger and room cooler (requiring low temperatures). To supply the 8000 Btu of cooling, 13,000 Btu must be sup-

continued

* *Selection of hot-side or cold-side storage affects the design capacity of the cooling unit. If hot-side storage is used, the capacity of the cooling unit may be based entirely on the cooling requirements of the conditioned space. However, cold-side storage necessitates a cooling unit having a capacity sufficient to utilize all the solar heat at the time it is collected. The fluctuation in solar energy thus would require a larger cooling unit with cold-side storage than with hot-side storage.*

† *COP, ratio of cooling obtained to heat input to the generator.*

Figure 1. Indirect-heated continuous solar absorption air-conditioner. Performance calculations based on this diagram.



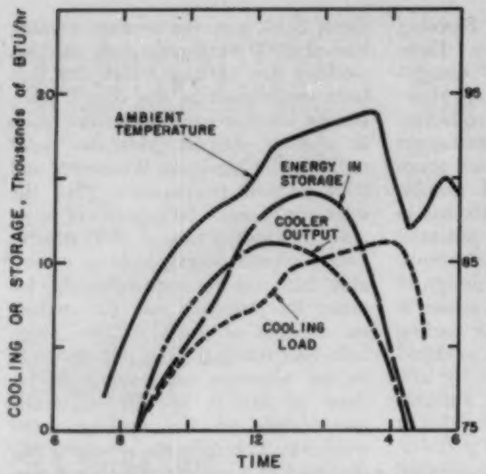


Figure 2. Performance of the solar cooler with cold side storage for a day similar to the design day.

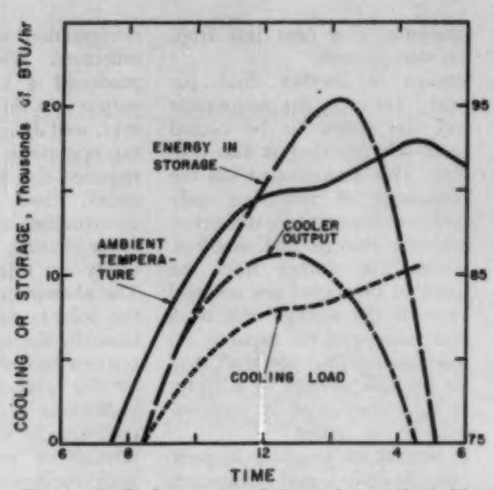


Figure 3. Performance of the solar cooler with cold side storage for a day of high storage requirements.

Solar space cooling

continued

plied to the generator. The sum of these two heat inputs to the system must be dissipated in the cooling water used in the absorber and condenser, or by other means. The system Freon 21-Tetraethylene glycol-dimethyl ether is used.

The performance of the solar cooler, with operation of the collector as a constant-flow water heater, with a maximum water temperature of 210° F, has been calculated on an hour-by-hour basis through the *design day*. The calculated total daily cooling capacities are 68,400 Btu for hot-side storage (at about 200°F) and 71,400 Btu for cold-side storage (at 50 to 70°F). The corresponding storage requirements are 19,000 Btu and 14,600 Btu. The hour-by-hour radiation and performance coefficients of both collector and cooler, with cold-side storage, are shown in Table 1.

Cold-side storage could be accomplished by placing the evaporator in the top of a water-tank storage unit, and withdrawing water from the bottom of the tank for comfort cooling. With the necessary temperature differences from evaporating refrigerant to water, and water to room air, the allowable rise in water temperature would be restricted to about 15°F. Cold-side storage of 14,600 Btu would then require an insulated tank of about 115 gal. capacity.

Calculated performance for two days. The *design* weather conditions were selected as representative of those under which a cooler would operate, but seldom are there days that approach the design conditions in all of their meteorological aspects. Figures 2 and 3 show the calculated performance of the solar cooler for two days of substantial cooling demand and illustrate the effects of combinations of meteorological conditions on capacity and storage requirements. Shown are the hourly changes of ambient temperature, cooling loads, cooler output and amount of useful storage, for water heating operation using cold-side storage. Hour-by-hour calculations of collector and cooler performance are based on the ambient temperature and hourly radiation data from Madison Weather Bureau records for each of the days. Cooling loads are taken as proportional to the difference between ambient temperature and 80°F.

Calculated performance for a day which approximates the conditions assumed in the design are shown in Figure 2. The ambient temperature is below 90°F in the morning and slightly above 90°F in the afternoon. Compared with design conditions, this results in reduced cooling load in the morning, and increased cooling load in the afternoon. The design storage capacity of 14,600 Btu is adequate to handle the 14,100 Btu requirement for this day. The total daily cooling load (to 5:00 p.m.) is 66,000 Btu; the cooler output is 64,000 Btu. Figure 3 shows a similar situation, but with more pronounced deviation from the 90° *design* ambient temperature. The increased loads on the system in the afternoon indicate a storage requirement of 20,300 Btu. The total day's cooling load is 61,000 Btu, while the cooling availability is 63,000 Btu. Other examples could illustrate days of excess or inadequate cooling capacity, and a requirement of nighttime cooling would substantially increase collector and storage requirements.

Discussion

The solar radiation data and calculation of solar heat collection in this design study are based on Madison conditions. However, heat recovery is approximately that which would be encountered on clear days on a collector of optimum orientation at most locations in the United States. The considerations outlined in this design study, and the approximate sizing of the equipment to produce a unit of cooling, are thus applicable to other locations. Assumptions and approximations concerning collector performance represent practical conditions which can be attained. While the operating conditions noted were selected after extensive study, a detailed optimization of the solar cooling system to minimize the total cost of cooling has not as yet been completed.

continued on page 78

Table 1. Design-day solar radiation on a collector tilted 35° to the south, and calculated collector, cooler and overall performance coefficients for water heating operation, cold-side storage.

Daylight Hours	Radiation Btu/hr. sq. ft.	Performance Coefficients: Collector	Cooler	Overall
11-12, 12-1	340	0.52	0.66	0.34
10-11, 1-2	310	0.49	0.66	0.32
9-10, 2-3	250	0.47	0.63	0.30
8-9, 3-4	190	0.38	0.56	0.21
Overall		0.43	0.64	0.28

Solar space cooling

from page 76

The ultimate choice of a cycle and type of operation, method of storage, and the sizing of the components, should be made on the basis of costs of components, of energy from conventional sources, and of a detailed study of the meteorological conditions in the area of application. A further important consideration is the relative magnitude of winter heating requirements and summer cooling requirements for a system which uses the collector and storage facilities for both operations, as the collector and storage capacities may be fixed by the requirements of either of the operations. In most space heating applications, an auxiliary (conventional) energy source will be required, and this source may also be used as an auxiliary energy supply for the cooling system. If 100% availability of cooling is required, an auxiliary source of heat energy must be provided in most climates to operate the cooler during prolonged cloudy periods.

Under the conditions assumed in this study, an overall COP of about ¼ is indicated (four Btu radiation incident on the collector will produce about one Btu of cooling, under good radiation conditions.) Thus the collector area requirements indicated by this study are about 160 sq. ft./nominal ton of cooling capacity for an 8-hr. day (or 480 sq. ft./ton-day of cooling) for a well designed collector with optimum orientation, a cooler with high coefficient of performance, and typical clear day radiation.

ACKNOWLEDGEMENT

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Presented at A.I.Ch.E. Salt Lake City meeting under the title, "Solar Absorption Space Cooling".

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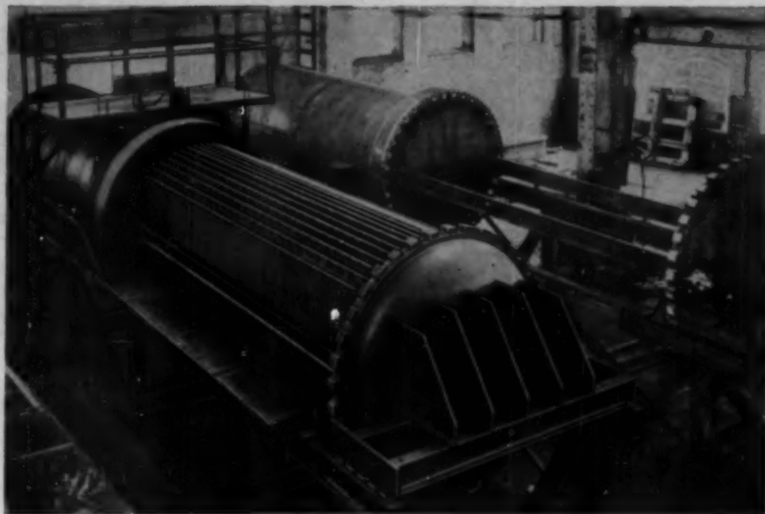

Montecatini to build giant petrochemical plant

Work has begun on Montecatini's new petrochemical plant at Brindisi, Italy. Estimated to cost $95 million, and planned as the largest of its type in Italy, the new plant is expected to go on-stream in three years.

Plastics, including polyethylene and isotactic polypropylene; polymers for synthetic fibers; aldehydes; alcohols; and organic solvents, will be produced at the Brindisi plant. The manufacturing unit is expected to be a large scale application of the concept of stereospecific analysis discovered by the scientist, Giulio Natta, and developed by the petrochemical firm.

Situated on a 1200-acre site, this largest Montecatini hydrocarbon facility will have a capacity of 700,000 metric tons a year. Total number of people employed is expected to run about 2500, with another 1500 engaged in related activity.

Construction of an $8 million nitrogen fertilizer plant in Bosnia agreed upon between the Italian companies, Montecatini and Ansaldo, and the Yugoslav "Rudnap" company.

An application of nuclear energy for process use will get under way next year in Norway. An atomic reactor now under construction will supply steam for the operation of a paper mill.

Mexico Refractories Co. will merge into Kaiser Aluminum & Chemical, according to an agreement reached by the two companies. The Mexico, Missouri, firm will operate as a division of Kaiser Chemicals. The combination of each firm's complementary refractory products is expected to put the new organization in a position to supply users a complete refractory service.

Subscriptions to the Journal of Heat Transfer, ASME publication, may now be purchased by members of AIChE at one-half the non-member rate. This is under the terms of a reciprocal agreement reached by both groups, in which AIChE volumes on Heat Transfer in its Monograph and Symposium Series are available to ASME members at a similar discount. The agreement extends for a trial period of two years.

industrial news

Industrial firms help train engineers

Recent additions to MIT's Chemical Engineering Practice School, which provides practical experience for young chemical engineering students, are Esso Standard Oil and American Cyanamid, both in New Jersey. Twenty students are assigned to projects at field stations at Esso's Bayway Refinery in Linden, and American Cyanamid's Bound Book organic chemicals plant.

In the Practice School program, established in 1917, students work on projects requiring initiative, in the application of basic scientific and engineering training for their solution. Setting the Practice School apart from the usual industrial training program is the presence of a full time MIT engineering faculty member at the plants. Problems covering all phases of engineering for student investigation are developed jointly by company representatives and the resident professors. The problems are then carefully appraised for educational value before assignments are made. Faculty directors follow the work of each student closely as consultants and advisors. Frequently, student solutions to the problems yield important technical contributions. Use of these results by the companies can greatly stimulate the confidence of students in their engineering ability.

The term runs for eighteen weeks, nine at each station, and the program, coupled with classwork at MIT, leads to an MS degree. Both graduate and undergraduate students are members of the course. Facilities at each station include a library, laboratory, conference room and study area. Quarters are provided for the students at Plainfield, New Jersey.

A $100,000 Product Control Center is under construction at Sun Oil's Marcus Hook refinery. The installation, believed to be the only one of its kind, will collect plant operating data. It will also continuously monitor the quality variances in important characteristics of petroleum product streams. Information will be gathered by viscometers, continuous chromatographs, boiling range recorders, density transmitters, colorimeters. The venture is jointly sponsored by Sun Oil and Genesys Corp. of Los Angeles.

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WHEN this missile "lifts off," Carlson special stainless steel plates help launch it into space. These plates are the high strength, precipitation-hardening grades. And there are sound reasons why these grades are used.

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Second, only Carlson produces these Armco grades in the heavier plate thicknesses. For applications where high strength at high temperatures and ease of fabrication are important, get plates in these grades from Carlson. We will be glad to work with you on specific applications.

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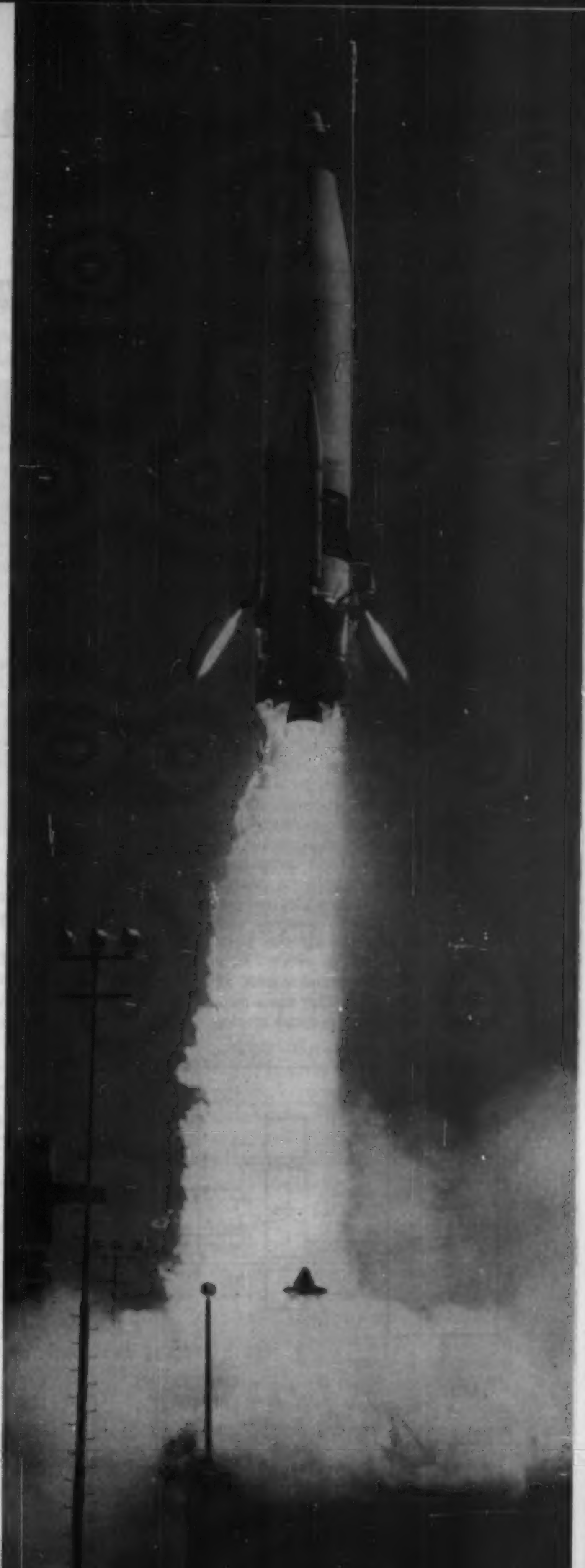


Photo of Atlas missile courtesy
CONVAIR ASTRONAUTICS,
A Division of General Dynamics Corp.

For more information, turn to Data Service card, circle No. 7

The outlook for computer control

Individual process controls are here to stay; computer controls will be in the nature of an additive refinement. We are a long way from achievement of complete computer control of industrial chemical production processes.

I. M. Stein, *Leeds & Northrup Co.*

Figure 1. Data logging system used in process control at Baton Rouge plant of Esso Standard Oil.

Some producers of computers who have only recently attempted to enter the field of automatic control of continuous processes are, perhaps, promising too much too soon. Among these newcomers to the automatic process control field are companies whose competence in the field of computer techniques is excellent, but there is much more to the automatic control of continuous processes than sound computer techniques.

Basic control systems are still undergoing development and improvement to make them better for today's needs and to adapt them to the needs of the future. About two or three years ago, some technologists active in the field of process controls expressed the view that it was not worthwhile to improve such direct control systems further because they would soon be made obsolete by the use of direct control from computers. It seemed inconceivable to many, however, that in large-scale continuous processes a single complex unit would be entrusted with the basic control, so that if anything went wrong with the one complex unit, all control would be lost. This same position is supported by the consideration that much of the first cost and the maintenance cost of such control systems would be necessary anyway, even though the attempt were made to substitute computer control. From a number of recent articles in the technical press, one gets the impression that the idea of replacing direct or "blind" control by computer control has largely disappeared.

Individual, process-variable controllers are here to stay, and computer controls will be in the nature of an additive refinement, so that if the computer should fail to function properly only the additional refinement which it contributes would be lost, and the conventional control system would continue to provide stable operation just as it did before adding the computer refinement.

Intermediate stage

As an intermediate step toward computer control, a satisfactory computer can be of great value in analyzing the static and dynamic characteristics of the process to determine where the process operation may be improved from a control point of view and to appraise the prospects of the advantages to be gained by adding computer control. A logging system provides a periodic read-out, in digital form, of all the process variables, and provides an auxiliary read-out, also in digital form, of abnormal performance at any of the control points or of any other process variables. This latter feature permits the plant operator to adjust the individual control points to give the optimum performance attainable in the process as it exists. Additionally, the computer may be used to calculate involved relationships and to print out "operating guide" information.

Both the intermediate and the ultimate use of computers to improve the control of continuous industrial processes require what is called the "programming" of the computer. This requires determining the static and dynamic characteristics of the process and then adjusting the programming element of the computer to take these characteristics into account.

It should be obvious that for the programming adjustments to be correct for a reasonable length of time, the characteristics of the process itself must be stable over that interval, regardless of such factors as changing ambient temperatures and cleanliness of the system. It is possible, by using what some control technologists have called "adaptive control", to have the computer automatically readjust its own programming to take into account changes in one, or a few, of the process characteristics; but, if many of the characteristics required such treatment, the use of adaptive control could readily become impracticable for one reason or another.

Industrial process control

Regarding continuous industrial processes themselves, the technolo-

continued on page 88

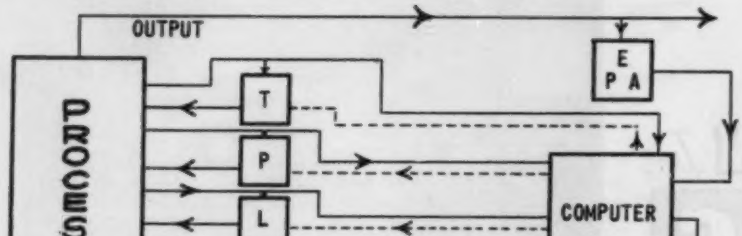


Figure 2. Typical schematic diagram for computation and data logging.

Computer control

from page 86

gists of the operating companies have made, and are making, extensive studies of process dynamics, but much remains to be done in this field before the prospects for full computer control can be properly appraised.

It is interesting to speculate as to what will place the ultimate limit on computer control of continuous industrial processes Will it be the limitations of computer controls, or will it be the limitations of the process itself? Some of the leading technologists in the process industries feel that the limiting factor will be the computer controls rather than the process characteristics. The writer, who is engaged in the development and production of computer controls, feels that the ultimate limit will not be in the controls. Based on past experience in the development of refined controls, there can be expected a sort of "see-saw" pattern in which both the controls and the process plant are continually improved with the limitation shifting from time to time from one to the other. At any one time, of course, the capability of the controls might be in advance of the capability of a particular process or plant to respond to the full capability of the controls, while in another particular process or plant the reverse might by true. Probably, the ultimate limit will be an economic one, wherein refinements in both the controls and the processes will have reached the point of diminishing return so that further refinements in either would not be economically justifiable. In any event, we are a long way from ultimate accomplishment in either category.

It is not clear whether the computers to be used in the ultimate developments will be of the digital or analog type. Probably, there will be need for both. For installations where they are applicable, analog computers, presently at least, are likely to be simpler, more reliable, and less expensive than digital computers. They are useful and rather widely used in "ratio" and "cascade" control systems. Analog computers, utilizing direct current signals for both the input and output circuits, provide great flexibility and permit combining the computer signals for various computing operations. This same flexibility makes these computers especially adaptable for use in end product con-

continued on page 90

Computer control

from page 88

trol from suitable analyzing instrumentation. This is an active and growing field.

Decentralization

In the development of large, continuout systems—where possible—it is better to segregate the whole complex process into several discrete major parts, and to do a very thorough job of controlling each of these parts, instead of attempting as the first step to control the whole comprehensive system. When really satisfactory control of each such discrete major part has been achieved, it should not be difficult to coordinate the several parts to provide sound over-all control, particularly if this ultimate goal is kept in mind from the outset. This procedure will not only shorten the time to achieve ultimate success but will produce more reliable over-all control of a comprehensive system.

Condensed from an address at the 14th Annual Symposium on Instrumentation for the Process Industries, Dept. of Chemical Engineering, Texas A & M.

A 300,000 square foot research, development and manufacturing facility in Houston, Texas opened by Southwestern Electronics Company. SIE produces control systems for the chemical process and petroleum transportation industries, as well as electronic test instruments.

A new research center will be constructed at the Newark, Delaware, headquarters plant of Continental-Diamond Fibre Corp. This will enlarge the current research area by 2½ times, and is part of the corporation's plan to centralize its entire research effort at the new facility.

A basic Russian language course for research personnel at Union Carbide Plastics is now underway at Union Junior College, Cranford, N. J. Part of an off-campus program of classes at Merck and CIBA, the class is taught by Savel Kendall, instructor at the college. Union Carbide, as part of its educational refund program, will return half the tuition to students who successfully complete the course.

A liquid metering device, the "Pottermeter" will be marketed by a new sales section in the Bowser organization, the Bowser-Pottermeter Division.

More on "Natural" rubber

Advances in the man made "natural" rubber field are again in the news as plans to commercially market synthetic diene and Coral rubber get underway at Firestone with the addition of a 30,000 ton manufacturing unit to the company's petrochemical plant in Orange, Texas. Brominated butyl, Goodrich's development, is already on the market under the name Hycar 2202.

Coral is Firestone's replacement for natural rubber, and synthetic diene is a rubber expander. Diene, combined with equal quantities of natural rubber, causes no loss of the qualities of the natural material, says Firestone. Diene has butadiene as its principle material, coral has isoprene. While they are both by-products of petrochemical operation, the supply of butadiene is plentiful, that of isoprene is not at present.

According to tests, improved crack and skid resistance, and better running temperatures result in tires of blended natural rubber and diene. Temperature build-up in truck tires is comparable to that of tires made entirely of natural rubber.

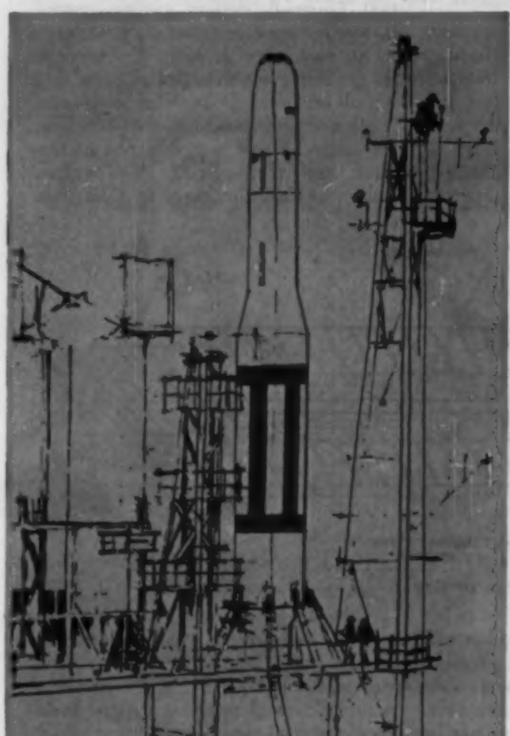
Goodrich's brominated butyl, when added to a batch of tree rubber, is said to improve the natural product so that it holds air as well as the best synthetic rubber. It is felt that the brominated butyl offers a solution to the problem of fortifying tree rubber against ozone damage. It also acts as a base for an adhesive which permits bonding of butyl rubber to metals or other rubbers. Brominated butyl is said to vulcanize faster than butyl rubber and thus is expected to reduce processing costs.

A gas processing plant at Nevis, Alberta, Canada, will be engineered and constructed for the Nevis Operators' Committee by the Fluor Corp. According to plans, yield will be approximately 43 million cubic feet a day of gas, and 125 long tons of sulfur.

Recent merger between Witco Organic Chemicals Division and Emulsol Chemical, Witco subsidiary, expected to result in a 50 percent expansion of Emulsol research facilities. Emulsol laboratories in Chicago are being consolidated into Witco's, and construction is now underway to accommodate the additional equipment and staff.

ONE IMPORTANT REASON WHY THERE CAN BE A BLASTOFF

The dome head you see at the right is part of what are familiarly known among the missiles people as "battleship tanks." That's because it is too heavy to be air borne. Yet it performs an important function in the missiles program. It is a part of heavy-walled units like those below which are used to test components, subsystems and systems for the TITAN missile by The Martin Company at its Denver facility. Graver's assignment was a number of dome heads and cones for this testing installation, another example of how Graver's century-proved skills with alloys and special steels are being employed in the missiles program.



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For more information, circle No. 57

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Plants and Offices Across America

Experience in high pressure technology

L. G. Stevenson,
Process Development Dept.,
Spencer Chemical Co.

Lessons learned about high pressure techniques and equipment from the design, construction, and operation of a high pressure polyethylene pilot plant at Spencer Chemical, Pittsburg, Kansas.

The ASME Unfired Pressure Vessels Code, and the formulas and concepts on which the code is based, are not adequate nor applicable in the high pressure range. There is, in fact, no such standard for high pressure design. In recent years, however, there have been written and published in the various trade journals many articles related to the various phases of high-pressure design. A rather extensive literature search should be the first step in designing a high pressure facility. A study of the various magazines and high pressure equipment manufacturer's catalogs will enable any competent engineer to become familiar with high pressure and high pressure equipment in a relatively short time.

A surprisingly large number and variety of types of standard high pressure equipment are readily available. Included are compressors for 30,000 lb./sq. in. and upward, intensifiers and pumps for 30-50,000 lb./sq. in., pipe, tubing, fittings, and valves for 100,000 lb./sq. in., reactors and vessels for up to 50,000 lb./sq. in., and control valves for up to 30,000 lb./sq. in.

Only very unusual items require original design and engineering, and, even then, in many cases standard pieces can be rather simply adapted to a new service. In one instance (Figure 1), a filter was needed for service at 30,000 lb./sq. in. Filter manufacturers would not even consider accepting an order for such a device. From a reaction vessel manufacturer, however, a shell was readily obtained, and it was a relatively simple matter to modify the reactor and install a standard automotive-type filter.

Soft materials for high pressure

Soft materials are widely used for making high pressure seals, although careful and sometimes costly engineering and workmanship are necessary to use them effectively. Unfortunately, resilient high temperature materials are not available at all except for special installations where stainless steel "O" rings can be used. The "O" ring is a doughnut-shaped member made of a resilient material. It is placed in a carefully sized and machined "O" ring groove. A partial seal is formed by the surfaces of the "O" ring so that the pressure exerts a deforming force on the "O" ring. The resilient "O" ring deforms into the line contact of the seal filling that line completely to form a leakproof seal.

Metal fatigue—major problem

In the operation of a high pressure plant, fatigue offers a continuing, never-ending problem. Many theories have been advanced, but as yet the subject of metal fatigue is not well understood and no good method of predicting fatigue has been published. Only actual tests of the equipment can foretell its life. When equipment, which has withstood original pressure tests and which has not been subjected to corrosion or erosion fails, the cause is fatigue. In the operation of a commercial plant, an adequate supply of spares can be, and must be, maintained for all equipment subject to fatigue failure. In pilot plant operation, however, it is very unusual to operate more than one line of equipment. When fatigue failure of pilot plant equipment does occur, some ingenious maintenance engineering is often required.

In the Spencer Chemical polyethylene pilot plant, this was the case with a booster compressor used to increase gas pressure from 15,000 to 30,000 lb./sq. in. Valve ports perpendicular to the bore of the compressor result in incalculable stresses adjacent to the ports. A fatigue crack developed parallel to the bore and progressed in the classic spiral manner to the surface where the valve seals were made. Failure of this compressor after about 600 hours–6 million cycles–caused no end of consternation as a replacement unit was at least six months away. However, the affected area was bored out and a liner or plug was machined and fitted into the compressor body. A seal was effected at the back and at the front. The valves seated against the plug. In this manner, the compressor was put back into service only three days after the failure occured. Actually, as the result of a metallurgical study, a fatigue-resistant material was found from which the plug or liner was made, and a design resulted which was superior to the original.

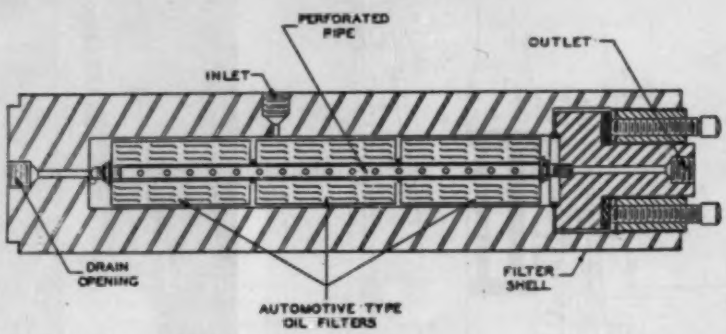


Figure 1. High pressure filter assembly.

False fatigue

In at least one instance, a comprehensive study was made of a fatigue failure problem which was later

continued on page 96

For more information, turn to Data Service card, circle No. 12

High pressure technology

from page 94

proved not to exist. After only a few hours of operation, the rupture disc failed on a pressure vessel which was subject to pressure pulsation. The disc, which was of conventional design, supplied by Black, Sivalls, and Bryson, was rated at 10,000 lb./sq. in. above the pressure at which failure occurred. After a second failure, the pressure differential was increased to 20,000 lb./sq. in.—the maximum possible. The instruments, which were the best and fastest available, indicated a pressure increase of about 400 lb./sq. in. at the time of failure. The suppliers were consulted and offered their opinion that their discs should be expected to fail in pulsating service at about ⅔ the rated pressure. Therefore, a shear type disc was designed and installed. Still, "fatigue" failure shut the operation down periodically. Special heat treatments and fatigue resistant metals were tried. Even the design was modified to minimize stresses—other than straight shear which does not produce fatigue. Still the discs "fatigued" and failed.

Finally, in desperation, a hydraulic system was designed which would eliminate pulsation from the rupture disc. (Figure 2). The free floating valve was held against a shoulder by a hydraulic pressure in excess of the vessel pressure—thus no pulsations were transmitted to the rupture disc. At this point, the "fatigue" problem disappeared into thin air and a severe operating problem developed—for this

continued on page 98

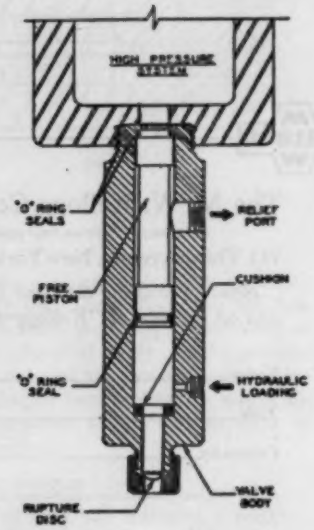
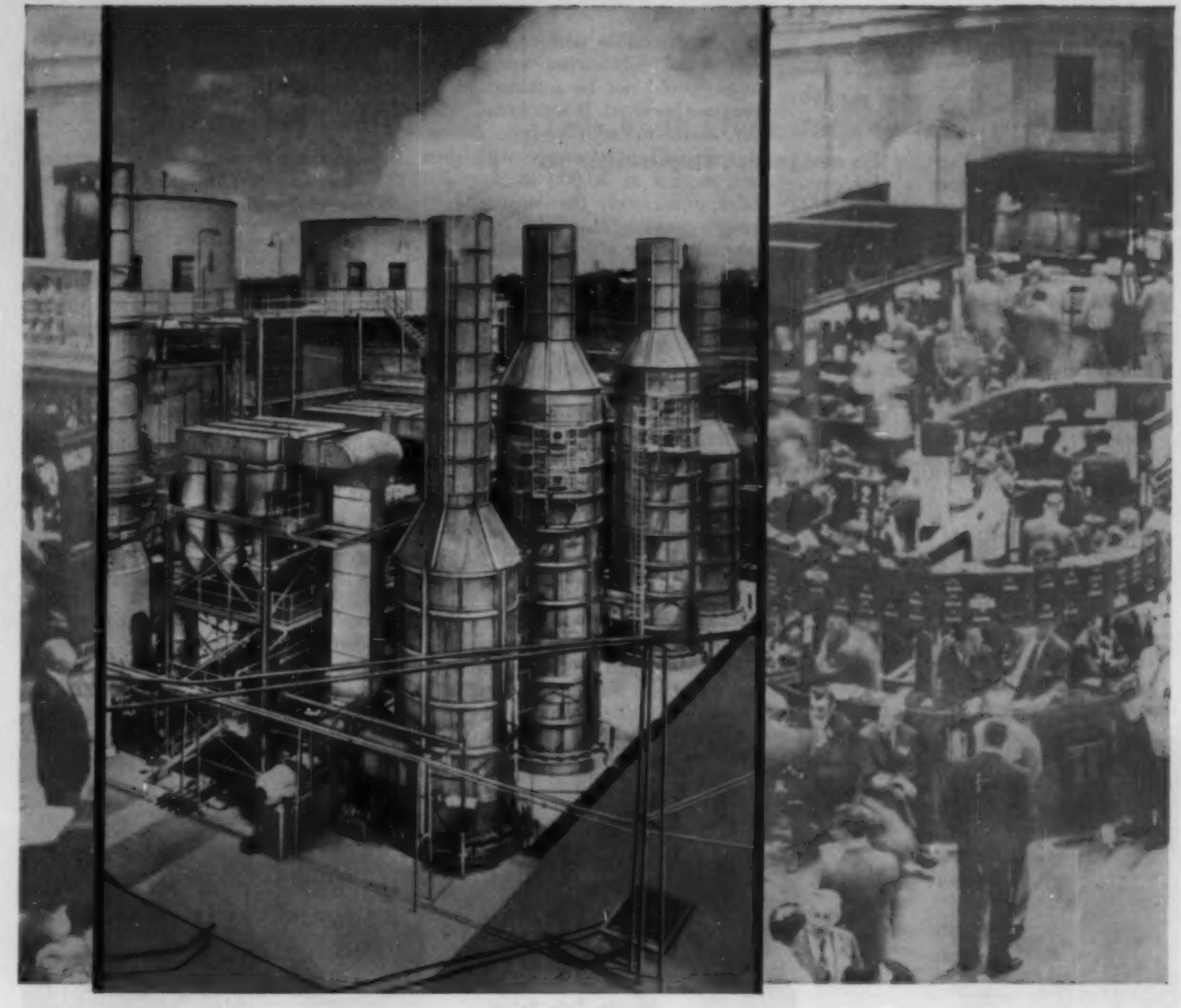


Figure 2. Hydraulic loaded relief valve.



American Cyanamid gets plant on time, within estimate through Pritchard's GOOD FINANCIAL DESIGN

Modern facilities like this new catalyst plant at Fort Worth, Texas have helped make American Cyanamid a foremost producer of industrial chemicals. The plant, which started with Cyanamid's development of a more efficient way to make a catalytic cracking catalyst, is a superb example of how client-contractor team-work can pay off. Cyanamid furnished the process; Pritchard supplied the plant design and construction service. By emphasizing the financial aspects of plant design while conforming to technical requirements, Pritchard engineers were able to make important savings on material and construction costs. As a result, the plant was completed below cost estimates and will make a better return on investment than originally anticipated.

Next time new facilities are being planned, put Pritchard on your team. In addition to top-flight engineering and years of construction know-how, you'll get the services of a company that can bring a business viewpoint to the planning table. Good financial design is your objective – Pritchard can best help you get it. Pritchard's experience, gained in serving companies such as American Cyanamid, Allied Chemical, Dow, Frontier, Liquid Carbonic, Pure Carbonic, Monsanto and Spencer Chemical, is at your service.

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For more information, turn to Data Service card, circle No. 27

High pressure technology

from page 96

system also failed. Thus, in this case, fatigue had never been a problem—instead, pressure increases in excess of 20,000 lb./sq. in. were occurring instantaneously—so fast, in fact, that the best instruments available could detect only the first 400 lb./sq. in. The determination and measurement of such phenomena was made more difficult because of the bulk and the massiveness of the high pressure equipment, and because the high pressure had to be placed in remote locations behind explosion-proof barricades.

Unusual properties

The anomalies to be expected in high pressure operations cannot be predicted accurately. These unusual properties may sometimes be deleterious though in some cases they may actually be beneficial. For example, at Spencer Chemical, it was desired to operate a rotary seal at 30,000 lb./sq. in. and 1,000 RPM. To get reasonable performance from such a seal, lubrication was a must. Grease could not be retained at the pressures involved. It was found, however, that an additive-free mineral oil increased in viscosity with pressure, so that at 30,000 lb./sq. in. it had approximately the consistency of heavy grease. Thus it could be pumped readily at low pressures; and at high temperatures it would not flow freely and was a very effective lubricant.

Such unpredictable properties can also cause unexpected difficulties. A liquid material was to be pumped to 30,000 lb./sq. in through about 15 feet of ¼ in. line. The material in question freezes at about 6°C, so the line was located inside the pilot plant building where the temperature could be maintained at about 25°C. The ¼ in. line plugged immediately each time the pumps were started, but was always clear when the plant was shut down and the line was opened. After two or three experiences of this kind, it was concluded, correctly, that the freezing point of the material was raised to 25-30°C by a pressure increase of 25-30,000 lb./sq. in. Determination of physical properties at such pressures is complicated tremendously by the unavailability of testing devices which can be made to function at extreme pressures.

Condensed from a paper presented at the Kansas City A.I.Ch.E. Local Section One-Day meeting, 1958.

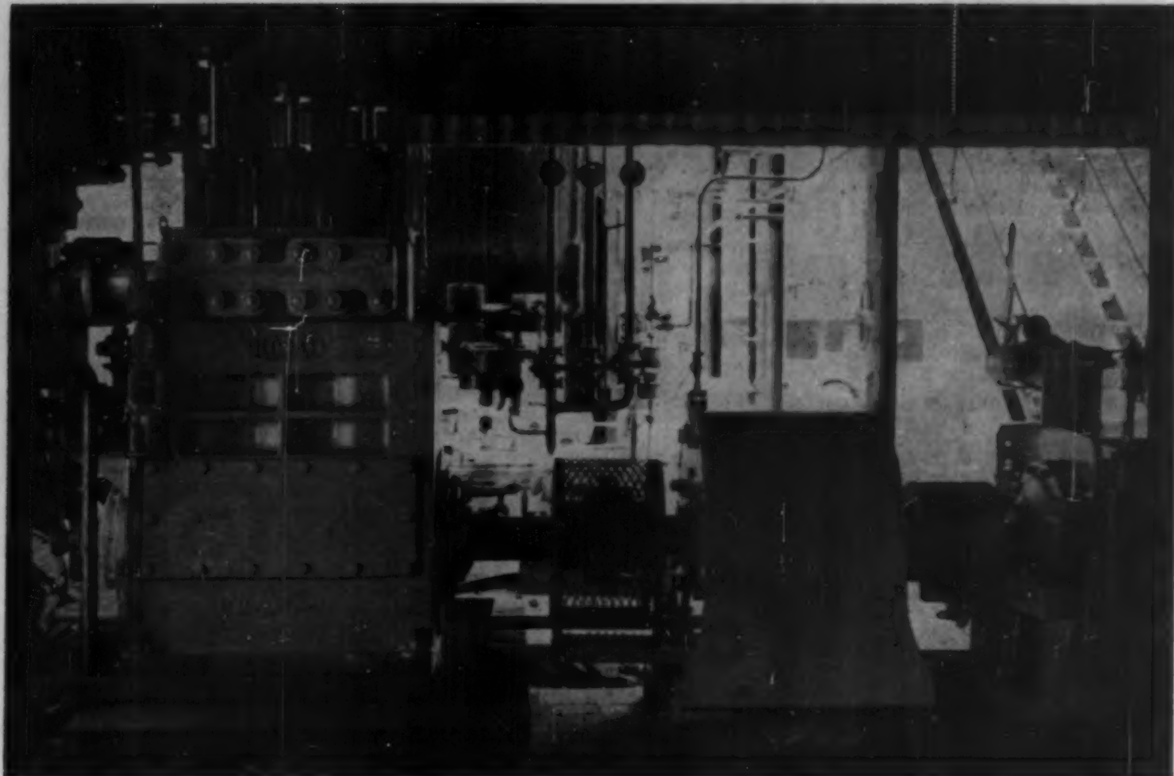
An analog computer facility acquired by Humble Oil & Refining under long term lease, for installation at the Baytown, Texas, refinery. Manufactured by Mid-Century Instrument, it is said to be one of the largest analog computer facilities used by industry. The facility will initially be equipped with 202 operational amplifiers, 60 electronic multipliers and 20 ten segment diode functions generators. It will be expandable to 516, 180 and 48 respectively.

Conversion of facilities to the manufacture of formica laminated plastics takes place at the St. Jean, Canada, plant of Cyanamid of Canada. The $1,500,000 change-over will increase the 17,000 square feet of floor space by more than 50 percent.

For more information, turn to Data Service card, circle No. 9

For more information, turn to Data Service card, circle No. 29

The following 4 Pages that appear to be missing are reader service cards and have been removed.



THE PRESSURES ARE HIGH...THE LIQUIDS CORROSIVE...THE PUMPS ARE ALDRICH...

At the Houston plant of Rohm & Haas Co., this Aldrich pump alternately introduces caustic and brine into one phase of the acrylate process for producing acrylic monomers.

The problem: Handle highly corrosive liquids at 3000 psi in a continuous process and *not* have severe maintenance problems.

What Rohm & Haas did about it. Company engineers specified Aldrich 1⅝" x 5" stroke Triplex Pumps for three reasons.

1. Compact, heavy-duty construction makes Aldrich pumps ideal for high pressure service.

2. Aldrich pumps are designed for easy maintenance. Fluid-end sectionalization permits quick removal of valves for inspection or replacement. No special tools are required.

3. Aldrich engineers can draw upon a vast store of experience when it comes to selecting the right materials for any pumping job. In this case, the entire fluid end . . . working barrel, suction and discharge manifolds . . . are forged Monel. Valve seats are Haynes Stellite. Valves and plungers are K Monel.

Results: According to the Plant Manager of the Houston plant, "maintenance requirements have decreased and pumping production improved. These Aldrich pumps lend themselves to easy maintenance."

How Aldrich can help you. Solving pumping problems like this requires specialized engineering skills and experience. We have those skills, and our experience comes from years of working with the chemical industry. We welcome the opportunity to discuss your specific problems . . . no matter what the liquid or how high the pressures. Aldrich Pump Company, 20 Gordon Street, Allentown, Pa.

the toughest pumping problems go to ALDRICH

For more information, turn to Data Service card, circle No. 38

CEP'S DATA SERVICE—Subject guide to advertised products and services

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 101

Equipment *from page 104*

Mixers, side-entering, propeller type (p. 77). Technical info, design data in Bulletin from Turbo-Mixer Div., General American Transportation. **Circle 11-3.**

Mixers, top-entering (p. OBC). Propeller types, 1/4 to 3 hp. Bulletin 103 from Mixing Equipment. **Circle 20-2.**

Mixers, top or bottom-entering (p. OBC). Turbine, paddle, and propeller types, 1 to 500 hp. Bulletin 102 from Mixing Equipment. **Circle 20-1.**

Nozzles, spray (p. 145). Complete Catalog from Binks Mfg. **Circle 31.**

Plasticimeter, recording (p. 142). Technical Application Bulletin from C. W. Brabender gives details of the "Plastograph." **Circle 70.**

Preheaters, air (p. 83). Case history describes savings with use of a Ljungstrom Air Preheater. Air Preheater Corp. **Circle 48.**

Pumps (p. 105). Consulting services on any pumping problem. Aldrich Pump. **Circle 38.**

Pumps, canned (p. 131). Pump and motor in a single, leakproof unit, no seals or stuffing boxes. Chempump. **Circle 26.**

Pumps, centrifugal, PVC (p. 98). All wetted parts of unplasticized, unmodified polyvinyl chloride. Data from Vanton Pump Div., Cooper Alloy. **Circle 35-2.**

Pumps, controlled-volume (p 21). Bulletin 440 from Lapp Insulator gives applications, flow charts, specifications, construction details. **Circle 68.**

Pumps, glassed (p. 121). Bulletin 725.2 from Goulds Pumps. **Circle 83-1.**

Pumps, propeller (p. 96). Bulletin 203-6 is a summary of chemical pump data. Lawrence Pumps. **Circle 102.**

Pumps, steam-jacketed (p. 121). Bulletin 725-D17 from Goulds Pumps. **Circle 83-2.**

Pumps, turbine (p. 145). Technical Bulletin 100 from Roy E. Roth Co. gives complete mechanical data and performance curves on turbine-type chemical pumps. **Circle 87.**

Pumps, vertical (p. 121). Booklets from Goulds Pumps. **Circle 83-3.**

Pumps, zirconium (p. 79). Gearchem pumps, made by Eco Engineering, claimed ideal for handling of hot acids, including hydrochloric and nitric. Technical data. **Circle 59.**

Recorder, oxygen purity (p. 144). Range 99 to 100% O_2. Info from Thermo Instrument. **Circle 71.**

Rotameters, bypass (p. 84). For measurement of flow in large pipelines. Bulletin 18B from Schutte and Koerting. **Circle 15.**

Screens, vibrating (p. 126). Catalog from Syntron gives complete data on all types of vibrating screens. **Circle 96.**

Screens (p. 146). Screen powders, liquids, slurries in 4 to 400 meshes. Details from J. H. Lehmann. **Circle 39.**

Scrubbers, fume (p. 36). Bulletin FW-10 from U. S. Stoneware describes the "Cyclonaire," new wet-bed scrubber available in capacities of 750, 1,650, 3,500, and 6,000 cu.ft./min. **Circle 28.**

Scrubbers, fume (p. 125). Complete Catalog from Croll-Reynolds on Jet-Venturi fume scrubbers. **Circle 78.**

Separators, entrainment (p. 4). Bulletin 21 from Otto H. York describes installations of the Yorkmesh Demister in scrubbers, absorbers, evaporators. **Circle 90.**

Sight Glasses, Pyrex (p. 143). Squares, rectangles, or odd shapes in 8 thicknesses. Technical data from Swift Glass Div., Swift Lubricator. **Circle 44.**

Transmitter, pressure (p. 111). Specially adapted for use with low-pressure fractionating columns, evaporators, vacuum crystallizers. Data from Foxboro. **Circle 106.**

Valves, alloy (p. 25). Technical details from Duriron Co. **Circle 40.**

Valves, alloy (p. 31). Specifications, performance data from Cooper Alloy. **Circle 34.**

Valves, gate, plastic (p. 98). Now available with socket-weld and threaded ends. Folder from Vanton Pump Div., Cooper Alloy. **Circle 35-1.**

Vessels, storage and processing (p. 135). In any metal, with any kind of corrosion-resistant lining. Data from Ellicott Fabricators. **Circle 56.**

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

EQUIPMENT

301 Analyzer, amino acids. Bulletin K5000 from Phoenix Precision Instrument gives technical details of new model for automatic analysis of amino compounds.

302 Analyzer, automatic. For analysis of trace materials down to parts per billion, accuracy of 1%. New 8-page Brochure from Technicon Controls.

303 Analyzer, oxygen. New system using mixed bed demineralizer cartridge and a packed column of pure thallium, is effective down to several parts per billion of dissolved oxygen. Details from Industrial Instruments, Inc.

304 Blenders, ribbon. Construction features, dimensional and mechanical specifications in new Bulletin 800-159 from J. H. Day Co.

continued on page 110

MATERIALS

356 Butyl Rubber. Catalog from Enjay gives chemical and solvent resistance, applications, many charts and graphs.

357 Coatings, corrosion-resistant. New Bulletin 259 from Wisconsin Protective Coating lists coatings for steel, concrete, wood. Also lists bulletins on specific applications.

358 Coatings, vinyl plastic. Data from B. F. Goodrich Industrial Products on new metal coating system for bonding plastic to steel.

359 Elastomers. Report from Thiokol Chemical on resistance of elastomers to high aromatic fuels.

360 Elastomer, synthetic, fluorinated. New "Fluorel" high-temperature elastomer said to have excellent chemical resistance, to be suitable for seals and linings in chemical processing equipment. Data from Chemical Div., Minnesota Mining and Mfg.

361 Glycols. New 80-page Booklet on industrial glycols from Union Carbide Chemicals. Properties, solubilities, conversion data.

continued on page 110

SERVICES

371 Design and Construction, anhydrous hydrogen chloride plants. Brochure from Girdler Construction Div., Chemetron Corp., gives operating requirements, capacities, product analysis, flow diagram.

372 Design and Construction, iron ore reduction plants. New 16-page Brochure from Koppers gives details of the Strategic-Udy process, including estimated capital and operating costs.

373 Design and Construction, zirconium plants. Design, engineering, construction of 1.5 million lb./yr. zirconium plant described in Brochure from Badger Mfg.

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You can take your choice of over 200 heat transfer equipment manufacturers when you are buying heat exchangers.

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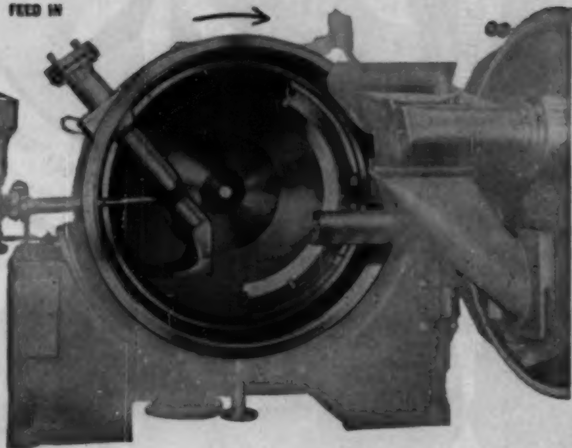
For more information, turn to Data Service card, circle No. 10

SHARPLES C-41 SUPER-D-HYDRATOR

powered for peak demands...

LOAD—0 to 152.5 miles/hour

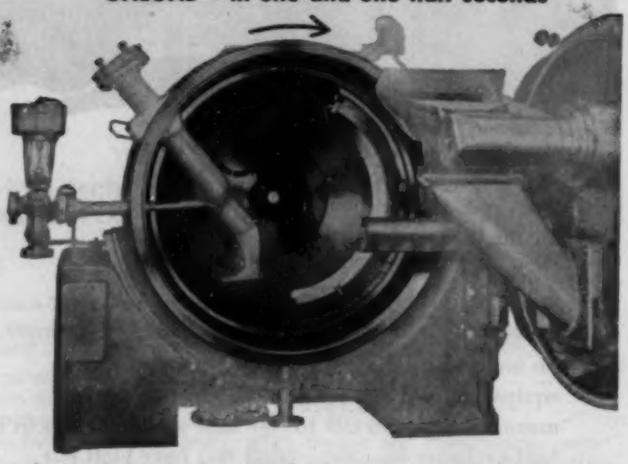
FEED IN



Sharples has designed the C-41 SUPER-D-HYDRATOR to utilize fully 150 or more horsepower because heretofore, insufficient power to load, accelerate and unload the crystals rapidly, has in many cases seriously limited crystal drying capacity.

With ample power available in the C-41, a thin cake of crystals is accelerated to rotational speeds up to 1250 rpm in 6 to 12 seconds—and is subjected to centrifugal force of 900 x gravity.

UNLOAD—in one and one half seconds



designed for both atmospheric and pressurized operation

At this high speed the thin layer of crystals quickly gives up its moisture—thus even slow draining crystals may be handled at high capacity.

The 300 to 400 lb. cake of dry crystals is deflected into the discharge chute by an hydraulically actuated knife—in less than one and one half seconds! There is no lost time for acceleration or deceleration. The SUPER-D-HYDRATOR automatically and instantaneously repeats the cycle as the centrifuge continually operates at full speed. Any part of the cycle may be adjusted while the centrifuge is in operation.

It will pay you to look into the exceptional capabilities of the C-41 SUPER-D-HYDRATOR.

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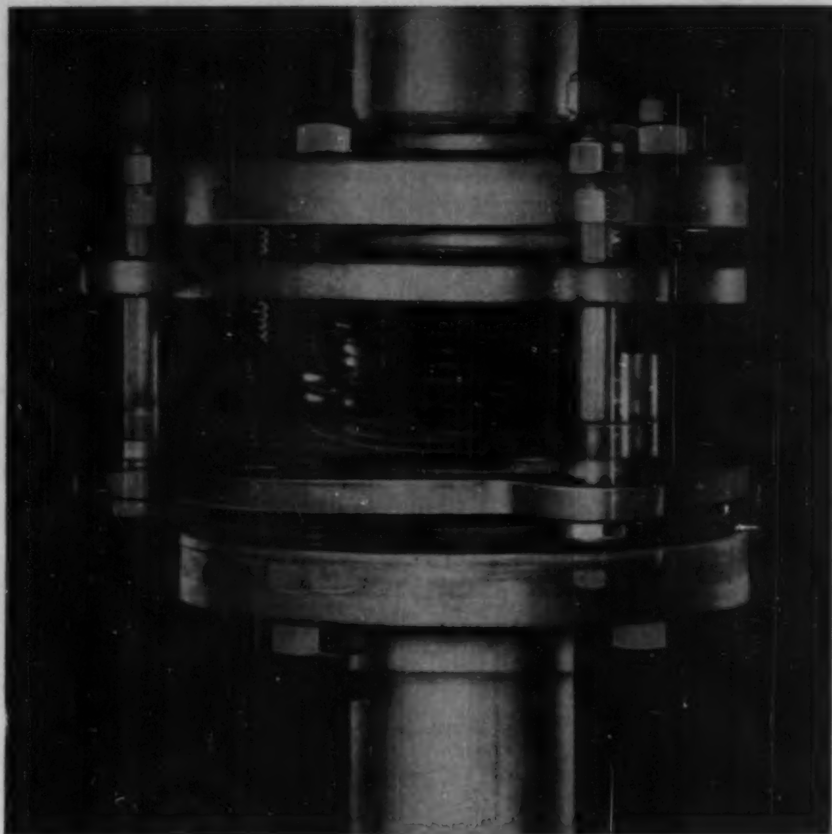

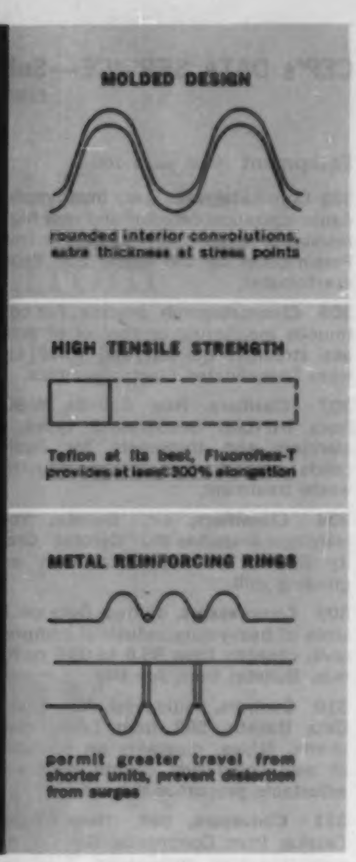

2 MILLION CYCLES AND STILL FLEXING!

...proving that this Teflon expansion joint—molded of Fluoroflex-T —outlasts most other materials and constructions

Chemical manufacturer: Tried Fluoroflex®-T joint, found it *still* flexing after *2 million cycles;* previously had averaged 100,000 cycles from machined Teflon® flex joint in pumping application.

Major industrial product company: Displaced one end of a special Fluoroflex-T bellows ¾-inch from its axis, rotated it around axis at 1,000 rpm. After *20 million cycles*, with still no sign of deterioration, test discontinued.

Petrochemical processor: Installed Fluoroflex-T joints to replace joints machined from Teflon. The Fluoroflex-T joints are still in service after nearly a year.

Fluoroflex-T flex and expansion joints perform so much better for three reasons: (1) *The material:* a patented compound of Teflon that combines high density with low crystallinity for optimum strength and flexibility. (2) *The process:* a unique technique for molding uniform convolutions with restraining rings. This gives undamaged grain structure, rounded interior convolutions and increased strength. (3) *The experience:* Resistoflex has been working with fluorocarbon resins since their inception. For fabricating with Teflon, such experience is *vital*. That's why Fluoroflex-T is Teflon at its best.

So, for corrosion-proof flex and expansion joints that give unsurpassed working life, specify Fluoroflex-T. Write for Bulletin B-1A. Dept. 235, RESISTOFLEX CORPORATION, Roseland, N. J. Other Plants: Burbank, Calif.; Dallas, Tex.

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®Teflon is DuPont's trademark for TFE fluorocarbon resins.

Complete systems for corrosive service

RESISTOFLEX

For more information, turn to Data Service card, circle No. 105

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

Equipment *from page 106*

305 Chromatograph, gas. Incorporates flame ionization detector and new high-resolution Golay columns. Details from Perkin-Elmer on the Model 208 Vapor Fractometer.

306 Chromatograph, process. For continuous monitoring or control of process streams. Bulletin and Price List from Consolidated Electrodynamics.

307 Clarifiers. New Bulletin W-800 from INFILCO describes 3 types of clarifiers and thickeners for liquid-solids separation in water, industrial waste treatment.

308 Classifiers, air. Bulletin from Hardinge describes the "Gyrotor" Gravity System, for operation with any grinding mill.

309 Compressors, oil-free. Data on 14 sizes of heavy-duty industrial compressors, capacity from 95.6 to 939 cu.ft./min. Bulletin from Joy Mfg.

310 Controls, liquid-level. New 6-page Data Bulletin 583 from Leslie gives charts, tables, diagrams on operation of new liquid-level control pilot with adjustable proportional band.

311 Conveyors, belt. New 88-page Catalog from Continental Gin Co. has comprehensive engineering data section with complete selection info.

312 Data Processing Systems. Bulletin from Burroughs Corp. describes its 205-median-priced electronic data processing system.

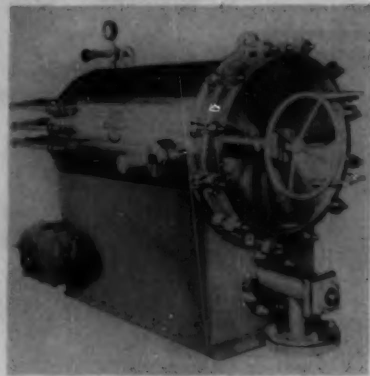
DEVELOPMENT OF THE MONTH

MASS FLOWRATE METER

(Circle 600 on Data Post Card)

A newly-developed primary element, which measures the mass rate of flow of gases, independent of pressure and temperature, is offered by National Instrument Laboratories. The element is basically an annular orifice in which the area of the orifice is controlled by a sealed bellows unit whose length is a function of the temperature and pressure of the flowing gas. The gas sealed in the bellows unit is the same as the gas that is to be measured, so that any deviation of the gas from the perfect gas laws is compensated for by having the density inside the bellows follow the same pressure-temperature relationship as the gas flowing in the line. The element is available in all stainless steel construction, except at low pressures where it is necessary to use phosphor bronze or brass bellows. For complete details, Circle 600 on Data Post Card.

DEVELOPMENT OF THE MONTH



NEW TYPE
DIATOMITE FILTER

(Circle 601 on Data Post Card)

The cake stability of a horizontal plate has been combined with a system for dry cake automatic discharge in a new design by Sparkler Mfg. The new Model HR is a totally-enclosed pressure type that can be cleaned with complete cake removal without opening the filter. The plates are precoated and operate in a horizontal position; this assures cake stability without danger of cracking or slipping. Individual plate shut-off valves and sight glasses make it possible to blow the cake completely dry even with a limited supply of air or gas. The plates are then mechanically rotated to a vertical position, and tapping on the external agitator bar will knock off the cake, or a vibrator can be used.

A screw conveyor removes the cake as a dry powder. Complete cleaning of the plates is performed without opening the filter. The unit can be furnished to operate completely automatically with electronic controls. For complete technical details, Circle 601 on Data Post Card.

314 Demineralizers. Complete specifications for fully automatic mono-column demineralizers in Brochure from Penfield Mfg.

315 Drives, adjustable-speed. Six-page Bulletin from Louis Allis covers redesigned "Ajusto-Spede" drive in ratings of ¾ to 7½ hp.

316 Dust Collectors. The "Air Tumbler" is said to offer high collecting efficiency, low operating and maintenance cost. Bulletin from Dust Suppression & Engineering Co.

317 Equipment, pilot plant. New Pilot Plant Equipment Manual from Doyle & Roth details complete line of standard columns, condensers, heat exchangers, pressure vessels, reactors, tanks.

318 Equipment, processing. New 48-page Catalog from Acme Coppersmithing & Machine includes equipment for distillation, evaporation, drying, crystallization, extraction, heat transfer, absorption, adsorption.

319 Feeders, vibratory. High-capacity Model V3B-70A, made by Eriez Mfg., is rated at 50 tons/hr. Dimensions, engineering data.

320 Flowmeters, turbine-type. Plus or minus ½% accuracy, pressures to 5,000 lb./sq.in., temperatures from minus 455 to plus 1,000°F. Data from George L. Nankervis Corp., Cox Instrument Div.

321 Heat Exchangers, aluminum. Sixteen pages of charts, technical info in Bulletin on "Reynolds Aluminum for Heat Exchangers." Reynolds Metals.

322 Heat Exchangers, graphite. Bulletin PB-103 from Carbone Corp. on the Polybloc graphite exchanger, featuring corrosion resistance, no cemented joints, continuous turbulence, interchangeable block construction.

continued on page 112

Materials *from page 106*

362 Heat Transfer Medium. Bulletin 200 from Thermon Manufacturing Co. describes applications of new heat conducting cement.

363 Hydrochloric Acid. Basic Reference Book from Dow Chemical. 44 pages, drawings, tables, graphs, reactions, uses.

364 Mercaptoethanol. New Technical Bulletin from Union Carbide Chemicals gives reactions and properties of 2-mercaptoethanol. Bibliography.

365 PE Tetrastearate. Product Data Sheet from Hercules Powder gives specifications, properties, compatibility, typical uses.

366 Phthalic Anhydride. Technical data and samples of Beta-S, new liquid dicarboxylic anhydride available from Heyden Newport Chemical. Indicated for curing of epoxy resins.

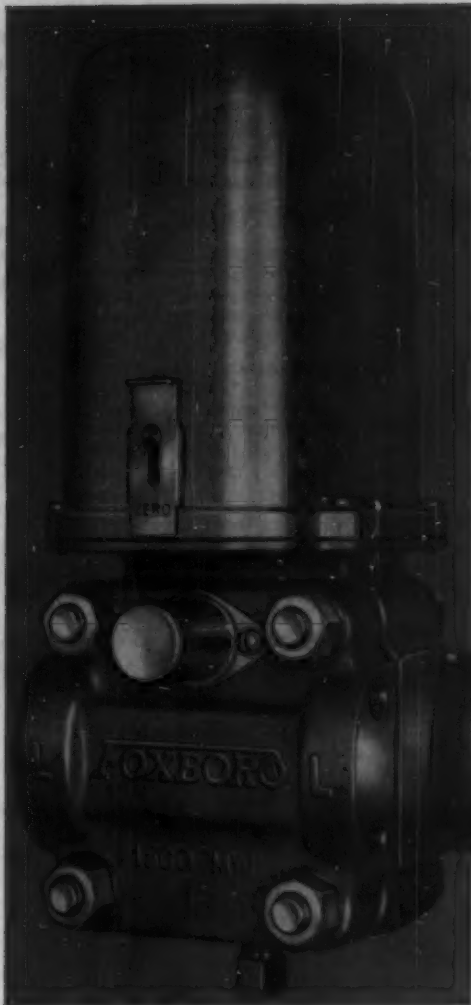
367 Polystyrene Latex. Technical Bulletin from Dow Chemical gives properties and applications of Latex 586, improved polystyrene latex for plastics and coatings uses.

368 Resins, polyethylene. New 22-page Brochure on Epolene C and Epolene N, non-emulsifiable low-molecular-weight polyethylene resins from Eastman Chemical Products.

369 Resins, silicone. Technical data from Silicones Div., Union Carbide, describes new, low-temperature-curing silicone resin XR-622.

370 Resins, urethane, foaming. Three new Bulletins from Thiokol Chemical give info on catalysts for use with "Rigithane 112," newly-developed foaming resin.

new
from
Foxboro



ABSOLUTE PRESSURE d/p CELL TRANSMITTER
with full-power 3-15 psi signal

Now there's a Foxboro d/p Cell designed specifically for low pressure measurement and transmission. It's the new Type 13AA Absolute Pressure Transmitter.

One side of the 13AA is evacuated, providing an absolute zero reference for the measurement of any process pressure. The 3-15 psi output signal has ample power for direct operation of standard receiver recorders and controllers.

This transmitter is simple in construction for trouble-free service. It provides for easy draining, steam tracing, and cleaning by regular maintenance procedures. Type 316 S.S. construction. Positive overrange protection to 1500 psi.

The 13AA Absolute Pressure Transmitter is ideal for use with such process equipment as low pressure fractionating columns, evaporators, and vacuum crystallizers. Ask your Foxboro Field Engineer for detailed information, or write for Bulletin 458-22A. The Foxboro Company, 934 Neponset Ave., Foxboro, Mass.

Specifications:

Range Spans: Adjustable 100 to 450 and 400 to 1500 mm of mecury

Output: 3-15 psi or 0.2 — 1.0 kg/cm^2

Accuracy: 0.5 percent of full scale span on most ranges

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process instrumentation

For more information, turn to Data Service card, circle No. 106

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

Equipment *from page 110*

from page 110

323 Heat Exchangers, impervious graphite. Bulletin from Falls Industries on new compression head design for all standard models from 21 to 470 sq.ft. heat transfer surface.

324 Heat Transfer Equipment. Bulletin 581 from Brown Fintube describes heat exchangers, fired indirect heaters, tank and process heaters, packaged boilers.

325 Heat Transfer Unit. Bulletin PD-1 from Tranter Mfg. gives engineering details, applications of the "Platecoil" heat transfer unit.

326 Instruments, pressure and temperature. Catalog 101-L from H. O. Trerice Co. describes full line of pressure and temperature indicators and regulators.

327 Materials Handling Systems. Folder 4153 from Dempster Brothers gives details of the "Dempster-Dinosaur," new system of materials handling that employs giant containers up the 40 cubic yards capacity.

328 Meter, dissolved oxygen. Automatically analyzes and continuously records dissolved oxygen in surface waters. Complete technical info from Hays Corp.

DEVELOPMENT OF THE MONTH

PHOTORECTIFIER PLATES FOR COMPUTERS

(Circle 603 on Data Post Card)

Newly-developed photorectifier plates, a product of Lincoln Laboratory, MIT, are claimed to increase the range and flexibility of digital computer systems by replacing arrays of diodes at a great saving in cost. The plates, made and marketed by Rex Corp. under the name of Rex-Array, are applicable to existing computers as well as to new units. They can be used in conjunction with any punched card system, replacing mechanical methods of film reading, card reading, character recognition, etc. A single Rex-Array is equivalent to a large conventional diode network, yet requires no soldering and utilizes up to one twentieth the space. While photo diodes have diode characteristics whether illuminated or not, photorectifiers operate only when illuminated. This enables activation of required networks by simple masking techniques. For complete details of this important new development in computer technology, Circle 603 on Data Post Card.

329 Meters, tank-level. Measures liquid level and tank contents from any distance. Bulletin 945 from Uehling Instrument.

330 Mixers, continuous. Catalog K-57 from Baker Perkins, Chemical Machinery Div., gives engineering specifications, applications of "Ko-Kneader" type continuous mixers.

331 Mixers, planetary. Designed primarily for solid propellants, new heavy-duty vertical planetary mixer is claimed suitable for chemical processing applications. Data from Baker Perkins, Chemical Machinery Div.

332 Piping, plastic. Handbook from Chemtrol describes technology of plastic piping systems. Many charts and tables.

333 Pulsation Dampeners. Bulletin D-858 from Ball Mfg. describes line of dampeners for reciprocating pump discharge lines.

334 Pumps. Catalog from Dorr-Oliver describes complete D-O pump line for chemical process and allied industries. Specifications, performance data, parts lists.

335 Pumps, high-temperature systems. Circular 214 from Dean Brothers Pumps describes complete line of pumps for high-temperature water systems.

336 Pumps, metering. New chemical-reagent head on standard controlled-volume diaphragm pump converts for handling corrosive liquids. Details from Lapp Insulator.

337 Reclaimer, oil. Technical details from Hilliard Corp.

338 Regulators, Thermon-jacketed. Sliding-gate pressure and temperature regulators now available with removable Thermon jackets. Bulletin J-160 from Jordan Corp.

339 Rotameters, armored. For fluid flow rate measurement and control at high pressures and temperatures. Bulletin from Brooks Rotameter Co.

340 Sampler, airborne particles. For collection of radioactive airborne particles. Operates on any vacuum or aspirator system. Bulletin A-100 from Machine & Instrument Design Corp.

341 Separators, cyclone. New model 36, made by Torit Mfg. operates in 4,000 to 6,000-plus range. Technical data.

342 Separators, entrainment. Bulletin from V. D. Anderson Co. gives details of purifiers, scrubbers, mist extractors, separators.

343 Spectrometers, mass. Bulletin 1824C from Consolidated Electrodynamics gives details of Types 21-610 and 21-620 for continuous or individual sample analysis.

344 Switch, flow. Can be used either to protect pumping units or as a flow alarm. Technical details from Ball Mfg.

345 Television, industrial. Bulletin from Kin Tel Div., Cohu Electronics, gives details of complete line of industrial television cameras.

345 Thermocouples. New Compact Chart of temperature-millivolt conversion tables from Thermo Electric Co. covers 8 different thermocouple calibrations.

347 Thermowells. Thermowell Material Guide from Thermo Electric facilitates selection of thermowells for over 325 different temperature measurement applications.

348 Tubes, heat exchanger. Reference Catalog on integral-finned tubes from Wolverine Tube. Sizes, alloys, heat transfer data, application data.

349 Union, forged-steel. New Catalog from H. K. Porter gives specifications, materials, pressure data.

350 Valves, corrosion-resistant. Chemical Resistance Data Sheet from Vanton Pump and Equipment lists chemical resistance of plastic and synthetic rubber materials of construction to 256 corrosive fluids.

351 Valves, feeder, rotary vane. Bulletin 24-D from Sprout, Waldron shows engineering drawings, design details, applications.

352 Valves, high-pressure. New non-sticking plug valve—tested to 15,000 lb./sq.in.—claimed 40% lighter than conventional tapered plug valves. Technical details from Hamer Valves.

353 Valves, plug. Catalog V-58 from Hydril gives technical details of new design — free-turning, positive-sealing, non-lubricated, bearing-mounted.

354 Valves, plug. Effective in temperature range from minus 300 to plus 400°F. Non-lubricated, with Teflon "O" rings. Bulletin from Wedgeplug Valve, Div. of Stockham Valves & Fittings.

355 Water Treatment Equipment. Comprehensive leasing plan for water, sewage, and waste treatment equipment offered by INFILCO.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 604 on Data Post Card.

Titanium for process equipment—New alloys

New alloy claimed to extend titanium's corrosion resistance into area of reducing media with no effect on mechanical properties or fabricability.

Titanium as a material of construction for chemical processing equipment may receive a much needed boost from a discovery just announced by Union Carbide Metals. Addition of as little as 0.1% palladium to titanium has been found to produce a new alloy resistant to boiling solutions of reducing acids (hydrochloric, sulfuric, etc.), without impairing the metal's well-known resistance to oxidizing acids (nitric, etc.). Mechanical and working properties are said to be completely unaffected.

Already in growing use for fabrication of pumps, valves, other chemical processing equipment, titanium has up to now been handicapped by its relatively poor resistance to reducing environments. For example, in a boiling 5% solution of hydrochloric acid, it dissolves at the rate of more than one inch per year. A 0.1% addition of palladium decreases the rate of corrosive attack to less than 0.01 inch per year. Equal improvement in corrosion resistance can also be effected by addition of most of the other noble metals—platinum, rhenium, ruthenium, iridium, osmium, rhodium, gold. Choice of palladium is dictated by its price, lowest of any of the noble metals.

Figure 1 (p. 120) shows the manner in which the corrosion rate of titanium in boiling hydrochloric of three different concentrations decreases with addition of a small percentage of platinum or palladium. Interesting is the fact that a maximum effect is attained at less than 0.1%; further addition produces no effect. Figure 2 compares the resistance of titanium and the new titanium alloy in reducing-type solutions; Figure 3 compares titanium and the new alloy with stainless steel and Hastelloy C in powerful oxidizers.

Economics and use patterns

At current prices, 0.1% palladium, quoted at about $19 per pound, would add about 28 cents per pound

continued on page 120

	Corrosion Rate (Mils/Year) Titanium	Titanium-Palladium
5% HCl, boiling	1,120	7
5% HCl, 190°C. (374°F.), O_2 sat.	Dissolved	5
5% HCl, 190°C. (374°F.), N_2 sat.	Dissolved	5
5% H_2SO_4, boiling	1,920	20
5% H_2SO_4, 190°C. (374°F.), O_2 sat.	Dissolved	5
5% H_2SO_4, 190°C. (374°F.), N_2 sat.	Dissolved	3
25% $AlCl_3$, boiling	2,020	1
50% formic acid, boiling	143	3
1% oxalic acid, boiling	1,800	45
50% citric acid, boiling	17	<1

Figure 2. Comparison of titanium and titanium-palladium alloy in various reducing-type solutions.

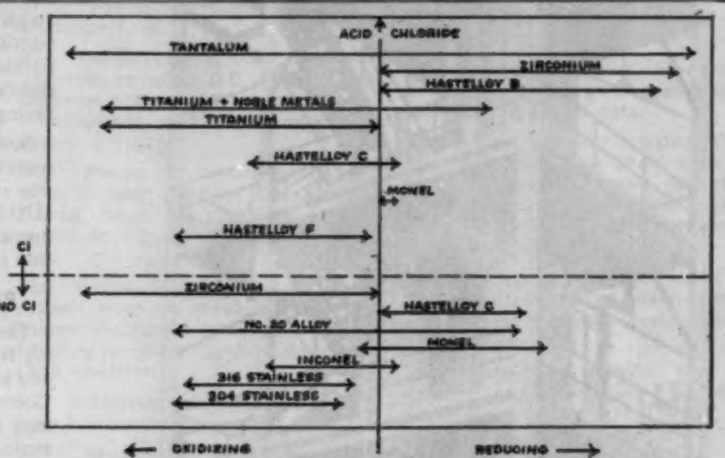
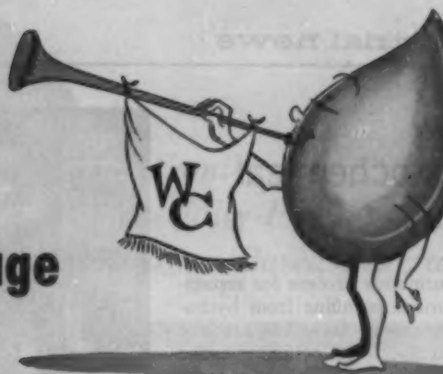


Figure 4. Comparison of titanium and titanium-noble metal alloys with other corrosion-resistant materials. The total area shown represents a variety of different types of corrosive environments. The vertical line in the center separates oxidizing environments on the left from reducing environments on the right. In addition, as one moves further and further to the left or to the right, the environment becomes more oxidizing or reducing and more aggressive. For example, this represents an increase in temperature and concentration. Also, moving from bottom to top, the environments show greater tendency to break down passivity illustrated by an increase in acid-chloride content. The solid lines with arrows at the end show the behavior of particular alloys. Each alloy will handle all environments below its solid line.

Environment	Corrosion Rate—Mils/Year Titanium-Palladium	Titanium	Hastelloy Alloy C	Stainless Steel
65% HNO_3 at 374°F.	<1	25	Dissolve	Dissolve
65% HNO_3 at 482°F.	Gain	Gain	Dissolve	Dissolve
Boiling 30% $FeCl_3$	<1	<1	Dissolve	Dissolve
Boiling 20% CrO_3	<1	<1	130	Dissolve
Boiling 10% HCl + 1.5% $FeCl_3$	3	6	Dissolve	Dissolve

Figure 3. Comparison of titanium and titanium-palladium alloy with stainless steel and hastelloy alloy C in very aggressive oxidizing environments illustrating the equivalence of titanium and titanium-palladium alloy and their superiority over iron and nickel-base alloys in such media.

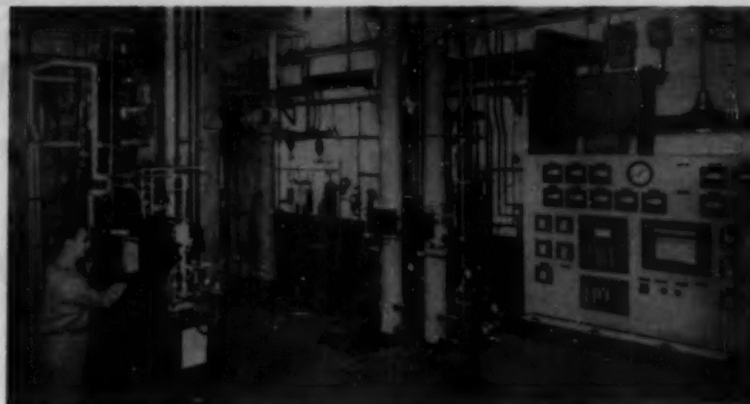


For more information, turn to Data Service card, circle No. 32

New Petrochemical Process

A new continuous process for separation of normal paraffins from hydrocarbon mixtures is claimed to produce cleaner burning, high octane gasoline components and valuable petrochemical sources at moderate cost. Tradenamed "Molex", the process was developed by Universal Oil Products.

The process removes low octane normal paraffins from gasoline mixtures by means of molecular sieves materials that permit some molecules to filter through, and block passage of molecules of a different shape. Thus it removes low octane, straight-chain paraffins from high octane, branched isoparaffins and cyclics. Normal paraffins can then be isomerized for fuel use, or converted to intermediate chemicals.



Tests for UOP's new process for removing normal paraffins were carried out in this Chicago pilot plant.

Said to be a less complex method than fractionation separation of C_6 and heavier straight chain compounds, the process makes a clean removal of normal paraffins. "There are occasions when Molex is not competitive with fractionation, other occasions when it is definitely superior, and still other occasions when it will perform a separation impossible by fractionation," according to UOP engineer D. B. Broughton. "Qualitatively, the process will consume less utilities than fractionation in any separation of normal paraffins from other hydrocarbons, and it can make

continued on page 118

For more information, turn to Data Service card, circle No. 18

Petrochemical process

from page 116

complex separations economically impossible with fractionation," UOP claims.

It has been the practice of many refiners to mask the poor quality of normal paraffins with high octane aromatics fuel components. By removing the low quality normal paraffins, the new process enables refiners to reduce the aromatics content of fuel blends, UOP points out. This is desirable since the high research octane number aromatics burn poorly under some conditions, resulting in a lower motor octane rating.

Pilot plant tests of the process show gains in research and motor octane numbers. A natural gasoline fraction containing 39 weight percent normal hexane had a leaded research octane number of 84.4, and a leaded motor number of 85.3. After passage through a Molex unit, the research number increased to 96.0, and the motor number to 97.4. The leaded research octane number of a light cut from a UOP reformer unit product increased to 102.0 from 94.5, and the leaded motor number rose to 101.2 from 95.1 under Molex treatment.

New petrochemical markets

While economical high performance automotive fuels are a main aim of the new process, it will also open new petrochemical markets to refiners, according to UOP. Economical separation of normal paraffins will stimulate manufacture of other petrochemicals, and better aircraft and missile fuels. Although normal paraffins are poor automotive fuels, they have the highest heat of combustion of any hydrocarbon—ideal properties for jet and rocket fuels. Also, abundant supplies of high purity normal paraffins could be the basis of synthesis of aldehydes, alcohols and other straight chain organic chemicals, UOP predicts. Normal paraffins also could be a preferred stock for high temperature pyrolysis to make ethylene and other intermediates, since paraffins are easily cracked.

An increase of more than 18 percent in the number of industrial radioisotope users in the chemical field was registered in 1958. The number of new companies of all types using radioisotopes increased nationally by almost 13 percent in the past year. Information is contained in a report "The Atomic Industry-1958", put out by the Atomic Industrial Forum.

For more information, turn to Data Service card, circle No. 77

New alloys

from page 114

to the price of titanium mill products. Recent prices for bars, plates, sheets, and wire have ranged from $4 to $14 per pound.

Figure 4 shows a comparison of titanium and titanium-noble metal alloys with other corrosion-resistant materials. It will be noticed that only tantalum exhibits superior resistance to the new alloys under severe oxidizing and reducing conditions in the presence of chlorides.

Carbide's data up to the present has been obtained only in the laboratory. However, Milton Stern of the company's Metals Research Laboratory in Niagara Falls, N. Y., discoverer of the new alloys, feels that in this case a jump can be made from the research stage into production without further extensive development work. A program for in-situ testing at actual plant locations is in the works, he added.

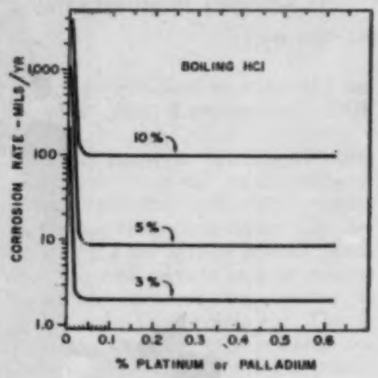


Figure 1. The effect of platinum and palladium additions on the corrosion rate of titanium in boiling hydrochloric acid solutions.

Marketing

Patent applications covering the development have been filed. Carbide says it does not intend to produce the alloys itself, but will offer licenses to titanium mill products producers, who in turn will sell to fabricators of processing equipment. Carbide will continue to produce titanium sponge.

A $50 thousand contract for the research and development of an isotopic dating technique has been awarded the Goodyear Co. The grant comes from the Office of Isotopes Development of AEC. Goodyear's work will be applied to representative pairs of selected isotopes, so that one isotope serves as a standard against which to measure the other and thus determine age.

A 10,000 metric ton phthalic anhydride plant will be constructed in Milan, Italy by ACNA (Aziende Colori Nazionali Affini). A subsidiary of the Montecatini group, largest Chemical Company in Italy, ACNA expects its plant to be finished in late 1959.

An $8 million credit to assist in the construction of an ethylene and polyethylene plant has been granted to Industrias Plasticas Argentinas Koppers, an Argentine company, by the Export-Import Bank of Washington. The plant, to be located near Buenos Aires, is expected to go into service in 1961, with an annual production in excess of 15 million pounds. Koppers International, C.A., subsidiary of Koppers, has a substantial interest in the firm. The grant is expected to help efforts to develop a petrochemical industry in Argentina.

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KANSAS CITY

16 sessions in three-day schedule

May 17-20th

Pipeline flow losses, compressor horsepower, loop lengths, distribution of gas or liquid flow—for all these calculations the computer is taking over. Four papers at the Monday morning session on *Computers and Pipelines* will tell you how it is being done in actual design and operating applications. Chairman will be R. L. McIntire of Datics Corp.

Also on Monday morning, G. C. Szego of Space Technology Laboratory will preside over a discussion on the extension of thermodynamics into the high-temperature region. The session—*Thermodynamics of Jet and Rocket Propulsion.*

Of peak interest will be the symposium on *International Licensing and Collaboration,* (Monday morning), led by Ralph Landau of Scientific Design. An extremely complex situation will be attacked from a variety of viewpoints—the trend toward secrecy instead of patents to protect technical

continued on page 124

Know your authors

Monday Morning

Giles Hunn McIntire Austin Martch Kniebes Wilson Rodean

Reynolds Baldwin Hall Torda Kuhn Buchler Asbury Knauff Gillespie Sheaffer

Monday Afternoon

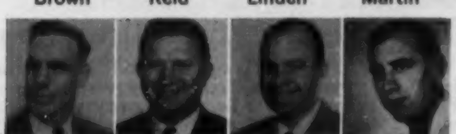
O'Brien Turner Hansen Hughes Meyers Voo Stuart Gunning Sommers

Agel Zwemer Dean McConnell Cubbage

Tuesday Morning

Grote Gerald Cestoni Ringelman

Brown Reid Linden Martin Petrick Swanson Sakiadis Arnold Henline Sission

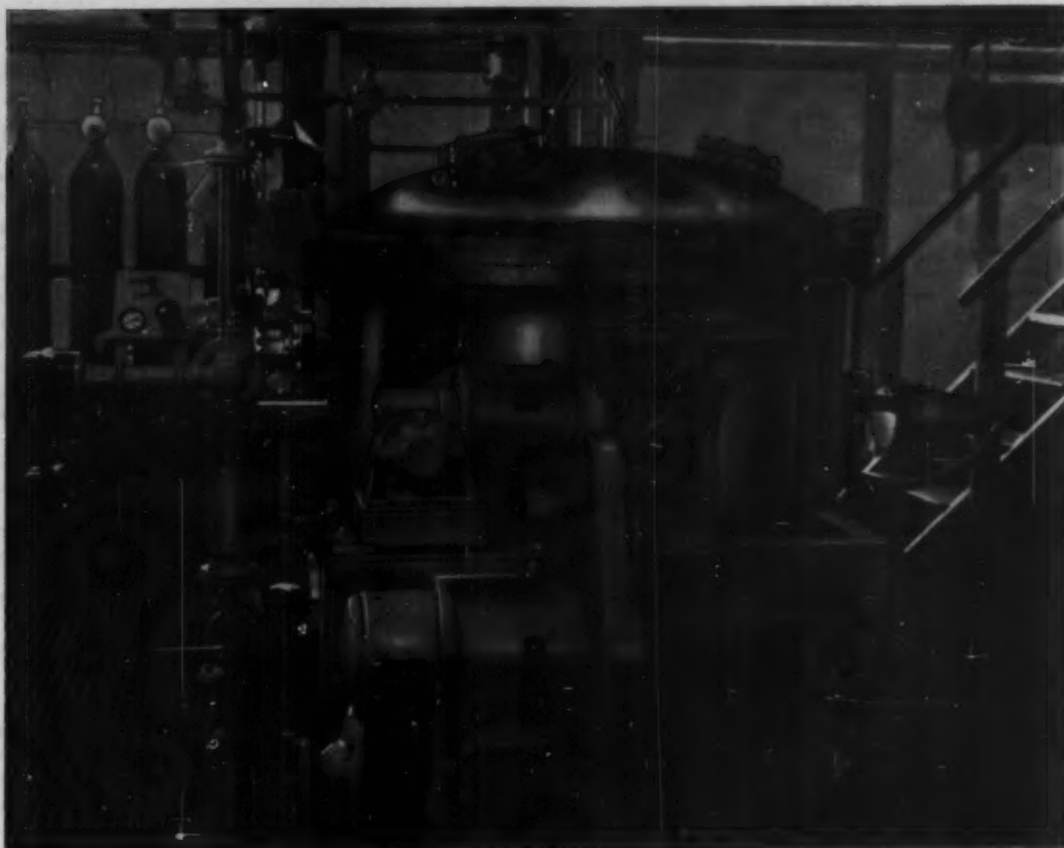


Bennett Hughes Adams Weaver

Tuesday Afternoon

Massimilla Betta Della Rocca Belton Burnet

Smutz Fleming Berry Koeller Adamson Arnold Stone Luffel Coats Tek



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Kansas City

continued from page 122

information, the effect of the newly-established European Common Market, the underlying threat of the economic "cold war" with the Soviet Union. (For further details, see Opinion & Comment, page 35, this issue).

At Kansas City, chemical engineers will have a unique opportunity to go back to school for an afternoon (Monday). The subject—clear technical writing: the teacher—Robert Gunning, who has conducted courses at many of the country's major companies, and who has been a pioneer in the development of standards for readibility. Although this session is probably aimed more at the young engineer who has yet to develop a definitive writing style, there is certain to be something for everyone here—old dogs *can* learn new tricks!

What to expect

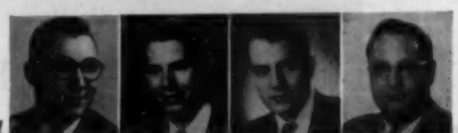
Growth Potentials of the Heavy Chemicals Industries in Central U. S., Monday afternoon, chairman N. J. Ehlers, will concentrate on resources and trends, will provide indices for location of new plants and facilities. A must for management-minded chemical engineers.

Processes will hog the limelight at the Tuesday morning *Petrochemicals* session (G. E. Montes). Alkylation of aromatics, ethylene oxide manufacture, acetylene and ethylene by pyrolysis, acetylene removal from ethylene—a design engineer's field day. Also assessed will be the role of the process engineer in petrochemical plants.

Tuesday afternoon's *General Session* will again lean to process considerations, with papers on the recovery of uranium, fused salt extraction of magnesium, purification of propylene. Chairman: G. H. Beyer.

Wednesday afternoon will emphasize process equipment in the two sessions on *The Present Status of Liquid Metals Technology*, presided over by H. M. Rodekohr of Ethyl Corp. Highlights will be data on how to design a heat exchanger for temperatures up to 1,500°F, and the latest designs in pumps for liquid metals.

Tuesday Afternoon *continued*



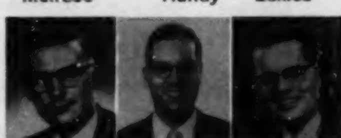
Churchill Thaller Thodos Sliepcevich

Smith Brewer

Wednesday Morning

Michaels Johansen Dunning

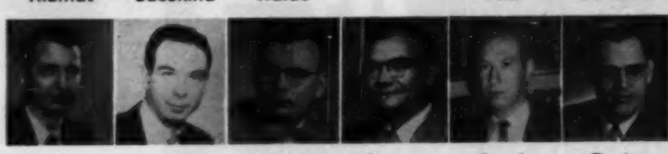
Melrose Handy Eckles Clifford Schroeder Raseman



Klamut Susskind Waide

Wednesday Afternoon

Fatt Denekas



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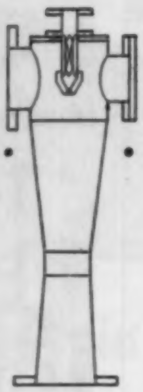

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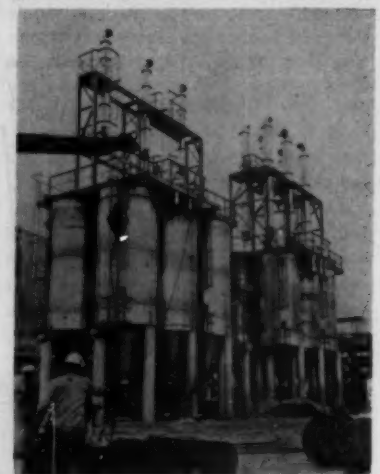
U.S.I. ups polyethylene output

Packaging uses seen due for greater share of market as U.S.I. puts new plant on stream. Film grade resin to be emphasized.

With the recent startup of its Houston, Texas, plant, U. S. Industrial Chemicals (National Distillers & Chemical) has an immediate 75 million pounds of new polyethylene capacity available, plans to double the plant's capacity by the end of 1960. Added to some 100 million pounds annually from its Tuscola, Ill., facilities, the new expansion will give U. S. I. a total yearly capacity of approximately 250 million pounds by 1960.

Present products at Houston are low density (.915-.924) and medium density (.925-.929). Packaging film, garment bags, housewares, and the like are expected to absorb the lion's share of its expanded production, says U. S. I. "Presently over 200 million pounds of this plastic are being used annually for transparent packaging films," point out company spokesmen, "and, by 1964, this figure will have grown to about 400 million pounds." By the same token, bakery



Product silage units at U. S. Industrial Chemical's new 75-million-pound polyethylene plant, Houston, Texas.

goods, which now consume about 3 million pounds, are expected to soar to 60 million annual pounds by 1964. Polyethylene-coated milk cartons, just introduced, are said to represent a potential 100 million pound market.

High density market lagging

Considerable development work has been done at U. S. I. on high density polyethylene, and the company claims an efficient and economic process. However, "current market conditions for this new high density material are such that we have no plans so far to put our knowhow to use," says the company. It is also reported that U. S. I. is carrying forward pilot plant work on polypropylene, other polyolefin copolymers, hopes to announce production plans "later in the year."

Feature of the new Houston unit is the fact that electronic instrumentation is used throughout—maker: Swartwout.

For more information, turn to Data Service card, circle No. 82

Atlantic City Meeting

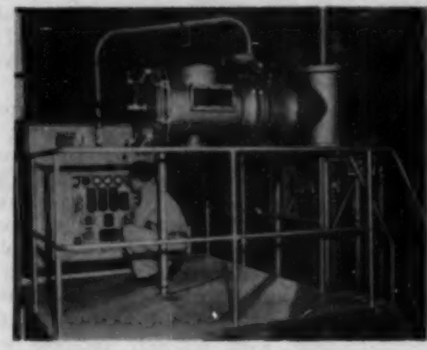
Animated scene in the Vernon room of the Haddon Hall. The occasion—the Sunday Get-Acquainted Party at A.I.Ch.E.'s Atlantic City National Meeting. A gala atmosphere pervaded the social program during the whole three days of the meeting, winding up with the traditional Tuesday night banquet and dance. Other diversions such as horseback riding and golf also attracted their share of enthusiasts.

An informal moment at the session on Business and Technology. Seated, left to right, are D. B. Keyes, New York consultant, K. M. Watson, Illinois Institute of Technology, and chairman John Happel of N.Y.U. Standing is W. G. Torpey of the President's Committee on Scientists and Engineers.

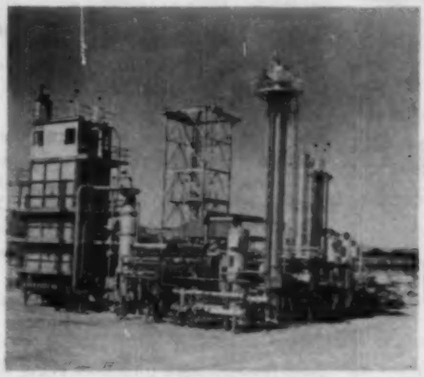
Panelists at Rockets, Missiles, and Satellites session are interviewed by the press. Left to right: H. W. Ritchey, Thiokol Chemical; G. C. Szego, Space Technology Laboratories; T. Dixon, Rocketdyne; Captain R. Truax, U.S. Navy; and E. Doll, Space Technology Laboratories.

Luncheon speaker Alan H. Shapley (right) of the National Bureau of Standards chats with A.I.Ch.E. vice-president Jerry McAfee (left) and president Donald L. Katz (center). At right Shapley and Katz are interviewed over Atlantic City's local radio station.

cep camera



An engineer operates the new electron beam welder designed and built by Air Reduction's Central Research Labs. to join reactive and high melting point metals, such as beryllium, tantalum, etc.



Said to be the smallest completely integrated Ammonia plant in the country, Apache Powder's Curtiss, Arizona, plant operates at direct production costs competitive with more conventional installations. The plant produces 30 tons a day, was designed and built by Girdler.

Cyclops, the highest capacity radioisotope machine ever installed for U. S. industry is now in operation at Cooper Alloy's Hillside, N. J., plant. The unit, rated at a capacity of 1500 curies, is used to X-ray stainless steel castings for process equipment. Here a valve body is being shot.

The thrust chamber for Rocketdyne's Jupiter missile engine operates at temperatures of 5000°. Cooling for the chamber is provided by the engine fuel which circulates through the thin tubes forming the chamber wall before being fed through an injector into the combustion area.

Saline water conversion —a major industrial problem

Saline water conversion is technically feasible, and has already been accomplished to some extent in certain areas, according to M. B. Andrew, staff hydro-mechanical engineer, California Department of Water sources. He addressed the **Southern California Section** (*R. D. Sheeline*) in January. The main obstacle so far has been that conversion is not *economically* feasible. But as water consumption mounts, and the development of remaining water sources becomes increasingly expensive, investigation of all possibilities for deriving water from saline sources becomes advisable, particularly in California where maldistribution of water exists with respect to major population centers.

State activities in salt water conversion consist of collection of data on existing and potential processes throughout the world, cooperation both with the University of California research and experimentation, and with the Office of Saline Water, Washington, D. C., which concerns itself mainly with applications.

Testing goes on in a 2000 gal./day vacuum flash distillation plant. This process holds promise where a low-grade source of heat is available. Solar and multi-effect compression distillation, ion exchange, and ultra-filtration are also being tested. A study contract held by Fluor Corp. involves making an engineering design study and cost estimate of a 20 million gal./day conversion plant which employs a pressurized water reactor plant of 350 MW capacity, and a multi-stage flash distillation system. In addition, Congress recently passed a bill providing for construction of five conversion plants, one of which was specified for the West Coast.

At present in the United States, there are few conversion plants, and none approaching a number of foreign installations in size. California's largest is a 144,000 gal./day unit of Pacific Gas and Electric Co. A brackish water demineralization application is the 28,000 gal./day membrane type plant being installed in Coalinga, a town in the San Joaquin Valley, by Ionics, Inc. This is the first incorporated city to use such equipment to produce potable water from brackish well water. Soft water produced by the plant will cost from $1.50 to $2.00 per thousand gallons, a considerable improvement over the current $7.00 per gallon price of imported drinking water in Coalinga.

On the question of energy resources, which have an important bearing on the economics of salt water conversion: atomic energy, although not yet competitive with power from a conventional fuel installation, is favored in a conversion. The reason: capability of large scale distillation plants to efficiently use low temperature heat. Converted sea water cannot, at this time, even remotely compete with imported water, although further investigations are indicated, was the conclusion of the speaker. Additional experimentation, he feels, will certainly bring forth improvements.

Utilization of hydrogen

Hydrogen Plant Processing, the purification and utilization of hydrogen in the chemical industry was the lead-off topic at the third annual All-Day Meeting of the **Southern Nevada Section** (*D. B. Erskine*), on January 17. Arne Eriksen, western district manager, Girdler Construction Division, Chemetron, headed the session. Other subjects covered were Chemical Feeders, Liquid and Solid, led by Paul Crowley, district manager, B-I-F Industries. He talked about the application and accuracy of various type feeders with means of tying them into complete process systems. Dale Nielsen of the University of California Radiation Labs, spoke at a session tilted "Project Plowshare", which analyzed the AEC investigation into the peaceful uses of atomic energy, such as making harbors, mining, and releasing oil from underground formations, etc. Also taken up at the meeting were: Acid Masonry Construction, recent developments in the field, and a look into the future; Mechanical Handling Equipment, including various types of conveyors, and Pneumatic Handling of Solids.

A one-day symposium on Catalysis was held by the **Pittsburgh Section** (*W. W. Lawrence*) on April 10. Speaker was Thomas J. Gray, of Alfred University. The meeting was

continued on page 132

continued from page 130

part of the Pittsburgh Bicentennial Association program of science activities and events in celebration of the bicentennial year.

Computers, economics and ceramics

A list of computer programs for IBM equipment and a demonstration of chemical engineering problem solutions was given the **Detroit Section** (*R. M. Lauritsen*) in January. Guest was Ching C. Tsao, former professor of chemical engineering at Purdue University. The following programs were taken up:

1. Rocket fuel evaluation—calculates the temperatures and chemical compositions inside the combustion chamber, and at the exit, the characteristic velocity and specific impulse.
2. Fractionator design—determines the optimum number of plates and diameter of a distillation tower by a combination of chemical, mechanical, and economic calculations.
3. Heat exchanger design—designs complete heat exchanger with the selection of shell diameter, baffle cut and tube passes.
4. Line sizing—determines the pipe diameter or pressure drop of single phase or two-phase flow of fluids.

"Red ink that was used in the ledgers last year may be used to paint the town in 1959", according to Paul J. Weber, assistant treasurer of Hercules Powder Co. Occasion was the March meeting of the **Philadelphia-Wilmington Section** (*D. G. Evans*). Weber predicted that 1959 would be a year of marked improvement if the present trend continues. He further stated that "revival in industrial production so far has been keeping pace with that of 1954-55. Because of the marked improvement that has taken place in industrial production, capital expenditures are likely to start advancing by the second quarter of the year. Retail trade is strong, and a rising trend is generally evident throughout the economy."

Recent developments in glass-ceramic materials, and in glass technology provide new classes of engineering materials previously unavailable. This was pointed out to the **Northern West Virginia Section** (*J. C. Leitinger*) in January. Production of 99.99 percent silica by condensation of silicon dioxide vapor permits manufacture of unlimited sizes and shapes. This alleviates dependence on naturally occurring quartz. Since size limitations are not a factor, applications in the missile field, e.g. nose cones, are of particular interest. Speaker was George McLellan, director of Technical Information, Corning Glass Co.

New section

The North Jersey Chemical Engineers Club, organized just a year ago, was formally awarded the status of section when F. J. Van Antwerpen presented the scroll at the December meeting.

Also meeting

Determination of an optimum running plan for a group of integrated

continued on page 134

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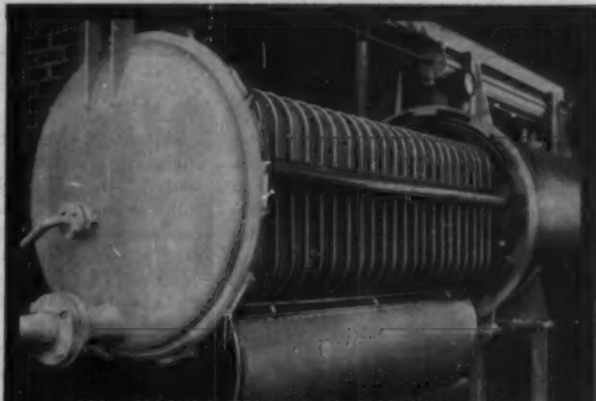

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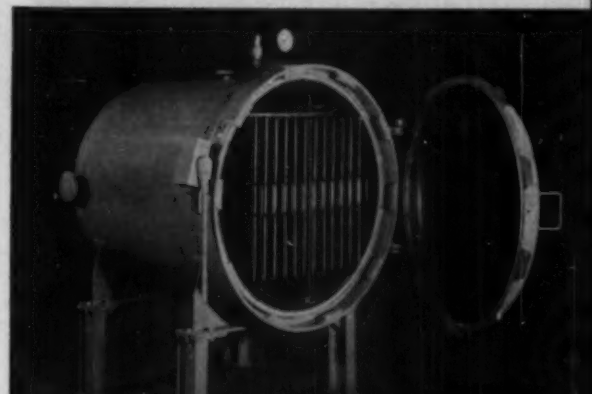

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continued from page 132

process and component blending operations was the problem taken up by Paul Stillson at the **New York Section** (*Herman Krinsky*) meeting in March. Stillson is supervisor operations research and industrial statistics at Shell Development. . . Selection of Outstanding Chemical Engineer of the Month is an innovation by **Northeastern New York Section** (*Walter L. Robb*). Award is given to the person guessing the answer to a semi-humorous unit operations problem presented at each meeting. . . Off-beat topic was chosen by **Western Massachusetts Section** (*J. F. Blumenfeld*) for its November meeting. Warren Wanamaker of GE, spoke on "Gold Mine Between Your Ears" Translation: creativity and the creative approach . . . Chemical engineers and chemists are the mainstays in synthetic fiber development, according to C. John Stezer, featured speaker at a recent **Central Ohio Section meeting.** (*Joseph H. Oxley*). His talk, "Synthetic Fibers" reviewed present and past technology in the eighteen year history of synthetic fiber manufacture. . . **Nashville Section** (*Robert D. Brown*) reports Annual All Engineers Banquet, jointly sponsored by all local engineering societies, was held in February. . . John Happel, head of Chemical Engineering Department at NYU, presented his philosophy and techniques for evaluating new business ventures. Audience consisted of the **Philadelphia - Wilmington Section** (*Louis P. Deis*). . . The chemical problems associated with maintaining a habitable atmosphere aboard submarines, particularly with respect to long submersion periods of nuclear powered boats, were explained to the **National Capital Section** (*V. A. Wente*) in March. Speaker was J. C. White, head of Electrochemistry Branch, Naval Research Laboratory. . . At the **New Jersey Section** (*R. J. Boyle*) in December, the always interesting question of the suitability of the engineer for management, and the alleged shortage of engineers, was covered by Frederick J. Gaudet, Stevens Institute of Technology, in a talk, "The Engineer as a Management Man". . . Leroy A. Griffith, chief of engineering Semi-Conductor Products Division, Minneapolis Honeywell, addressed the **Alton-Wood River Section** (*A. W. Frazier*) in January, on instrumentation and the effect of semi-conductor devices on it . . . Widely varying topics were covered at two recent **Bartlesville Section** meetings (*Leo J. Dagley*). Acetylene, modern manufacturing methods, held the floor in November, with Marcel J. P. Bogart summarizing the five major processes now in use. In December, members heard a forecasting of business conditions, with Marshall Milligan of Tulsa University giving his views of recent federal legislative controls against inflation . . . Orrington E. Dwyer talked to the **Rochester** (*Charles R. Adler*) and **University of Rochester Sections** in February on the liquid fuel reactor for nuclear power . . . A joint dinner between the Engineering Society of Western Massachusetts and the **Western Massachusetts Section** (*A. W. Andrews, Jr.*) heard Applications of Optics to Industry, a talk by John C. Milligan, vice president of Kollmorgen Optical Co. in Northampton . . . A lecture on future fields for chemical engineers was delivered to **Northeastern New York Section** (*Walter L. Robb*) and senior RPI students in November . . . Gerald W. McCullough of Phillips Petroleum, discussed management positions for engineers before the **Texas Panhandle Section** (*J. R. Roney*) and ASME in January . . . Basic chemical engineering aspects of missiles and rockets was the common interest topic bringing together the **St. Louis Section** (*A. W. Frazier*), and the St. Louis Rocket Society in February. Wilburn A. Riehl of the U. S. Army Ordnance Missile Command at Redstone Arsenal, Alabama, was the speaker . . . The **Boston Section** (*Ralph L. Wentworth*) took a look at one of the cornerstones of science and engineering at the February meeting: theory. T. K. Sherwood of the MIT Chemical Engineering Department led the discussion. Guests of the Ichthyologists were local ACS members . . . Sources of ionization radiation available, how it differs from other sources of energy, and the direction of experimental investigations were outlined by Thomas J. Hardwick, of Gulf Research & Development, to the **Pittsburgh Section** (*V. N. Hurd*). Occasion was a joint meeting between with the American Nuclear Society in December . . . Yuba, Buffalo chemical equipment fabricating firm, toured by **Western New York Section** (*Reed B. Garver*) in February.

For more information, turn to Data Service card, circle No. 56

future meetings

1959—MEETINGS—A.I.Ch.E.

• Kansas City, Missouri, May 17-20, 1959. Hotel Muehlebach. **A.I.Ch.E. National Meeting.** Gen. Chmn.: F. C. Fowler, Consulting Chem. Engr., 7518 Troost Ave., Kansas City, Mo. Tech. Prog. Chmn.: Fred Kurata, Chem. Eng. Dept., Univ. of Kansas, Lawrence, Kansas. (See page 122.)

• Storrs, Conn. August 9-12, 1959. Univ. of Conn. **A.I.Ch.E-A.S.M.E. Heat Transfer Conferences.** Prog. Chmn.: M. T. Cichelli, Eng. Research Lab., DuPont, Wilmington, Del.

• Austin, Tex. Sept. 9-11, 1959. Univ. of Texas **Mid-West Cong. on Fluid & Solid Mechanics.** Co-sponsored by U. of Tex., A.I.Ch.E. & others. Tech. Chmn.: M. J. Thompson, U. of Tex. Complete MS by June 1, 1959.

• St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting.** Gen. Chmn.: W. M. Podas, Asst. Rsch. Dir., Economics Lab., Guardian Bldg., St. Paul, Minn. Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc. P. O. Box 1370, Rochester 3, N. Y. **Size Reduction**—J. W. Axelson, Johns-Manville, N. J. **Missile Construction Materials**—B. M. Landis, Missile Div., Lockheed Aircraft, Palo Alto, Calif. **Physical Properties of Liquids**—S. E. Isakoff, DuPont Co., Eng. Dept. Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—A. H. [illegible]aker, 164 [illegible], Minneapolis 3, Minn. **More Research for Your Dollars**—T. S. Mertes, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa. **Process Control**—I. Lefkowitz, Case Inst. of Techn., Cleveland, Ohio. **Chemical Warfare**—Co-Chmn.: L. E. Garono & E. J. Gruen, Army Chem. Corps. Bldg. 250, Baltimore, Md. **Safety in Air and Ammonia Plants**—W. A. Mason, Dow Chem. Co., Midland, Mich. **Management of New Product Development**—L. B. Hitchcock, Consultant, 60 East 42 St., New York 17, N. Y. **The Chemical Engineer and Professional Societies**—C. R. Ringham, Phillips Petroleum Co., Bartlesville, Okla. **Axial Dispersion in Chemical Engineering Problems**—J. R. Fair, Jr., Monsanto Chem. Co., Sta. B, Dayton 7, O. **Student Program**—A. G. Fredrickson, Chem. Eng. Dept., U. of Minnesota, Minneapolis, Minn. **Selected Papers**—W. E. Ranz and H. S. Isbin, Dept. of Ch.E., U. of Minn., Minneapolis, Minn.
Deadline for papers: May 27, 1959.

• San Francisco, Calif., December 6-9, 1959. Sheraton Palace. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: Mott Souders, Jr., Shell Development Co., 4560 Horton St., Emeryville 8, Calif. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. F. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combustion**—C. J. Marsel, NYU, University Heights, New York 53, N. Y. **Secondary Oil Recovery Methods**—F. H. Poettman, Ohio Oil Co., Littleton, Colo. **Financing in the Chemical Industry**—**Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry**—J. L. McCarthy, Dept. Chem. Eng., U. of Washington, Seattle, Wash. **Turbulence and Turbulent Mixing**—T. Baron, Shell Devel. Co., Emeryville, Cal. **Electro-Chemical Engineering**—C. W. Tobias, Dept. Chem. Eng., U. of Cal., Berkeley, Cal. **Outlook for National Resources**—C. Meyer, U. of Calif., Berkeley, Calif. **Student Program**—D. M. Mason, Stanford U., Calif. **Selected Papers**—M. Manders, Union Oil Co., Rodeo, Calif.
Deadline for papers: August 6, 1959.

1959—A.I.Ch.E. Local Section

• New York, N. Y. (six Tues.) Mar. 24-Apr. 28, 1959, Chrysler Bldg. **New York Section A.I.Ch.E.** Lecture series on Reactor Design (See Mar. CEP, p. 142). G. T. Skaperdas, M. W. Kellogg for details.

• Stillwater, Okla. Apr. 25, 1959. Eng. Bldg., Okla. State U. **14th Ann. Tri-State Meeting, Bartlesville, Tulsa, & Cent. Okla. Sections A.I.Ch.E.** AM: Gen. Tech. Sess. Luncheon

Addr.: D. L. Katz. PM: Panel discussion—Design & Select. of Proc. Equip. For info contact E. K. Arnett, 1211 N.E. 30th, Oklahoma City 11, Okla.

• St. Louis, Mo. May 1, 1959. Coronado Hotel. St. Louis Section A.I.Ch.E. One-Day Technical Meeting. Chmn.: J. F. Adams, Monsanto. AM Gen. Sess: Progress in the Nuclear Field—D. L. Katz, Mich. U. AM Sess. A: Nuclear Technology—M. W. Marsh, Chmn. Development of TBP-Hexane Process for Uranium Purification—W. G. Philoon, Mallinckrodt; Fabrication of Reactor Fuels & Fuel Elements—G. W. Tompkin, Mallinckrodt; Reactor Training Program at Mo. School of Mines—W. H. Webb, Chem. Dept. AM Sess. B: Distillation—L. E. Stout, Jr., Chmn. Pilot Plant Studies on Packed Column Fractionation—W. G. Knapp, Monsanto; Comparison of Various Distillation Trays—J. S. Mocsek, Monsanto; Use of Digital Computer for Distillation Calculations—L. Cooper & W. E. Ball, Monsanto; Luncheon Spkr: D. L. Katz. PM Gen. Sess: J. F. Adams, Chmn. Recent Developments in Mass Transfer. PM Sess. A: Stream Pollution—M. P. Lux, Chmn. Stream Pollution Policy & Criteria—D. B. Morton, Illinois Dept. of Health; Evaluation & Abatement of Industrial Waste Problems—D. W. Ryckman, E. D. Edgerley, and N. C. Burbank, (all) Washington U., St. Louis; Waste Reduction in a Chemical Plant—P. B. Hodges, Monsanto; Panel Discussion—Morton, Ryckman, and Hodges. PM Sess. B: Heat Transfer—J. N. Holsen, Chmn. Simplification of Heat Transfer Calculations through Equip. Standardization—W. J. Davis, Monsanto; Heat Transfer in Rapidly Settling Slurries—C. W. Roos, Monsanto; Recent Trends in Russian Lit. on Heat Transfer Technology—W. P. Armstrong, Washington U.

• Elizabeth, N. J., May 12, 1959. Winfield Scott Hotel. 10th Ann. Technical Symposium New Jersey Section A.I.Ch.E. Solids Mixing and Continuous Processing. For details: Samuel Rock, Jr., E. R. Squibb & Sons, New Brunswick, N. J.

1959—Non-A.I.Ch.E.

• New York, N. Y. Apr. 28, 1959. Hotel Shelburne. Assoc. Consulting Chem. & Ch. E. Inc. Industrial & Educ. Devel. in Soviet Union. . . . London, G. B. May 11-13, 1959. Inst. of Ch.E. Brit. Conf. on Automation & Computation in Proc. Develop. & Plant Design. . . . Houston, Tex. May 18-20, 1959. Shamrock-Hilton Hotel. ISA—New Techniques in Analytical Instr. for Labs. & Process Plants. . . . Los Angeles, Calif. June 22-26, 1959. Hotel Statler. Tech. Session, Air Polution Control Assoc. . . . University Park, Pa. June 14-18, 1959. Penn. State. Seminar: Air Pollution Abatement by Electrical Precipitation. . . . Berkeley, Cal. July 22-25, 1959. U. of Cal. 1st Int. Conf. on Waste Dispos. in Marine Environment. . . . Berkeley, Cal. Sept. 2-4, 1959. U. of Cal. Cryogenic Eng. Conf.

1960—MEETINGS—A.I.Ch.E.

• Atlanta, Ga. Feb. 21-24, 1960. Hotel Biltmore. A.I.Ch.E. National Meeting. Gen. Chmn.: J. W. Mason, Dean, Coll. of Eng., Georgia Tech. Tech. Prog. Chmn.: F. Bellinger, Georgia Tech., 225 North Avenue N. W., Atlanta 13, Ga. Kinetics—C. D. Holland, Chem. Eng. Dept., Texas A&M, College Sta., Texas. Pesticides—(2 sessions) D. J. Porter, Diamond Alkali, Box 348, Painesville, Ohio. Nuclear Engineering—D. S. Arnold, Nat'l Lead, P. O. Box 158, Mt. Healthy, Cincinnati 31, O. Petroleum, Turpentine, and Solvents; Rubber and Plastics Applied to Textile Fibers: John Warner Chem. Div., Goodyear Tire & Rubber, 1485 E. Archwood Ave., Akron 16, O. Bioengineering-Radioistopes; Pulp and Paper; Engineering Sales; Rockets and Missiles—R. B. Filbert, Jr., Battelle Mem. Inst., 505 King Ave., Columbus, O. Management of Small Plants; Engineering Education; Mineral Engineering—W. A. Koehler, West Virginia U., Morgantown, W. Va. Fundamentals. Selling; By and To Small Plants—J. T. Costigan, Sharples Corp., 501 5th Ave., New York 17, N. Y.

• Mexico City, Mexico, June 19-22, 1960. Hotel Del Prado. A.I.Ch.E. National Meeting. Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 109, Tuscola, Ill. Chemical Engineering in Latin America—John Mayurnik, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. Petroleum Production—F. W. Jessen, Dept. Petroleum Eng., U. of Texas, Austin, Tex. Minerals and Metals—D. B. Coghlan, Foote Mineral Co., Lancas-

continued on page 138

future meetings

continued on page 137

ter Ave., Berwyn, Pa. **Distillation Equipment**—R. Katzen, 3736 Dogwood Lane, Cincinnati, O. **Biochemicals and Foods**—E. L. Gaden Ch.E. Dept., Columbia U., New York 27, N. Y. **Selected Papers.**

• Tulsa, Okla., Oct. 2-5, 1960. Hotel Mayo. **A.I.Ch.E. National Meeting.** Gen. Chmn.: E. W. Kilgren, P.O. Box 591, Tulsa, Okla. Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Foams—Their Use and Control**—C. S. Grove, Jr., Syracuse U., Collendale, Syracuse 10, N. Y. and R. L. Tuve, U. S. Naval Resch. Lab., Washington 25, D.C. **Computers as Management Tools**—R. Cziner, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Chemical Reactions Induced or Modified by Radiation**—J. J. Martin, Dept. Chem. Eng., U. of Mich., Ann Arbor, Mich. **Transport Processes in Petroleum Recovery; Advances in Refinery Technology; Petrochemicals, Natural Gas, and Natural Gas Liquids; Pilot Plants and Scale-up; Corrosion and Materials of Construction; Statistics and Numerical Methods Applied to Engineering; Comparative Economics of Various Energy Sources for Process Heat; Safety in Air and Ammonia Plants; Safety in Refinery and Natural Gasoline Plants; Area Industries; Conservation and Utilization of Water.**

• Washington, D. C., Dec. 4-7, 1960. Statler Hotel. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: J. L. Gillman, Jr., 1700 K St. N.W., Wash. 6, D.C. Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va. Tentative Program framework: **Chemical Engineering in Govt. Programs. Agency Oriented: Nuclear Energy, Health, and Education; Agriculture; Foreign Assistance Programs; Resource Development; Utilization and Reclamation; Naval Warfare Technology; Land Warfare Technology; Chemical Warfare, and Basic Research. Subject Oriented: Doing Business with the Government; Fluid Particles and Aerosols; Combustion Materials Deterioration; New Process Techniques; Unsteady State Instrumentation; Computer Control of Processing Units; Missiles and Rockets; Design Techniques for Very Large Systems; Information and Communication; Characteristics of Portable and Expendable Plants and Equipments.**

1960—MEETINGS—Non-A.I.Ch.E.

• Moscow, USSR, June, 1960. 1st Congress of International Fed., Automatic Control. To cover areas of **Theory, Hardware & Applications of Automatic Control.** U.S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill. completed papers by July 15, 1959.

1961—MEETINGS—A.I.Ch.E.

• New Orleans, La. Feb. 5-8, 1961. Jung Hotel. **A.I.Ch.E. National Meeting.** Gen. Chmn.: M. M. Gilkeson, Dept. Ch.E., Tulane U., New Orleans, La. Tech. Prog. Chmn.: H. L. Malakoff Petroleum Chem. P.O. Box 6, New Orleans 6, La. **Kinetics of Catalytic Reaction; Brainstorming Technical Problems; Petrochemicals—Future of the Industry on Gulf Coast; Solids—Future Processing Technologies in the Petroleum Industry; Education and Professionalism; Mathematics in Chemical Engineering; Liquid—Liquid Extractions; New Processes in the Area; Water from Sea Water.**

• Cleveland, O. May 7-10, 1961. Sheraton-Cleveland. **A.I.Ch.E. National Meeting.** Gen. Chmn.: T. J. Wash, Case Inst. of Tech., Cleveland, O. Tech. Prog. Chmn.: R. P. Dinsmore, Goodyear Tire & Rubber Co., Akron 16, O.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.

Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.
Preparation of Catalytic Cracking Charge Stocks and Quality Criteria Therefore:

continued on page 140

future meetings

from page 138

Wheaton W. Kraft, Lummus Co., 385 Madison Av., New York 17, N. Y.
Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.
Hydrometallurgy—Chemistry of Solvent Extraction: O. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.
Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods Des Plaines, Ill.

Author Information

Procedure in submitting papers:

1. Obtain four copies of "Proposal to present a paper before the A.I.Ch.E.," plus one copy of "Guide to Authors" from Secretary, A.I.Ch.E., 25 West 45th St., New York 36, N. Y.
2. Send one copy of completed form to Technical Program Chairman for meeting selected from above list.
3. Send another copy to H. D. Guthrie, Shell Oil Co., 50 West 50th St., New York, 20, N. Y. (Chmn. Program Comm.)
4. Send third copy to Editor, Chemical Engineering Progress, 25 West 45th St., New York 36, N. Y. Paper will automatically be considered for possible publication in A.I.Ch.E. Journal.
5. If desired to present paper in a selected symposium, send fourth copy to chairman of the symposium.
6. Prepare five copies of manuscript. Send one copy each to Symposium chairmen, Technical Program chairman, or both copies to latter if no symposium is involved. Other three copies should be sent to Editor, C.E.P. Presentation at meeting offers no guarantee of acceptance for publication.

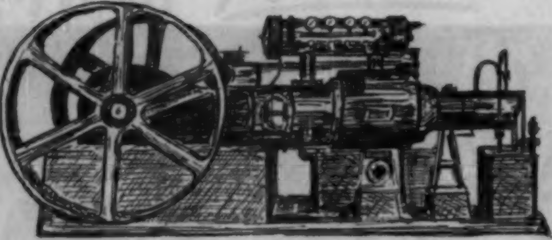
An additional 680,000 barrels of capacity has been acquired by General American Transportation at its Corpus Christi tank storage terminal. This brings facilities up to 3,039,000 barrels, an increase of 34 percent over previous capacity at the Texas terminal. Acquisition includes a dock for tankers and one for barges.

A 150 million cubic-feet-per-day gas processing facility has been completed by the Fluor Corp., Ltd. The plant is located near New Orleans, and is operated by the Texas Natural Gasoline Corp., joint owner along with Tennessee Gas Transmission Co.

A 3000 barrels a day sulfuric acid alkylation plant at Houston, Texas, has just been finished for Petro-Tex Chemical. Part of the plant capacity will be used to produce alkylate for Plymouth Oil from feed supplied by the latter.

A new group, the Plastics and Elastomers Division, has been formed at Hercules Powder's Research Center at Wilmington, Delaware. The unit is the result of expanded product development work on thermoplastic polymers, thermosetting resins, and filled and reinforced plastics.

HIGH PRESSURE COMPRESSORS



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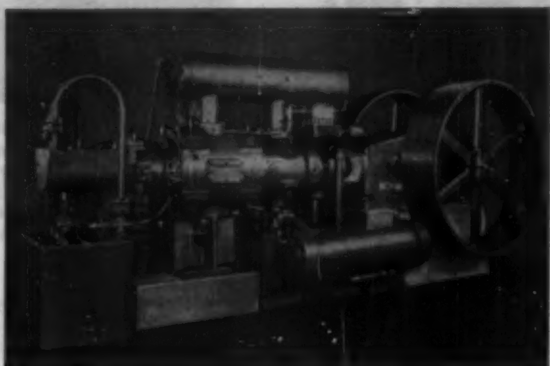

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Joseph H. Koffolt, winner of the Technical Man of the Year Citation, shown with previous winners at the Columbus Technical Council Engineers' Week Dinner, where the award was presented. L. to r.: Gordon B. Carson, vice president and former dean of Engineering at Ohio State University, Mr. Koffolt, and R. B. Filbert, Jr., chief of the Division of Chemical Engineering Research at Battelle Memorial Institute. Filbert is the first recipient of the award, and a former chairman of the Central Ohio Section, A.I.Ch.E.

Joseph H. Koffolt, Chairman of the Department of Chemical Engineering at Ohio State University, and a director of A.I.Ch.E., was named winner of the Technical Man of the Year award by the Columbus Technical Council. The annual award was established by the Council in 1957. Each of the twenty-three technical societies making up the council nominate one candidate, and the winner is chosen by a committee of six judges who are leaders both in academic and local government circles. The citation is based on character, professional competence, and service to profession and community.

Koffolt, nationally known in his field, returned to the campus in 1948 after extensive industrial experience. His work includes contributions to technical publications as well as research papers. Much credit for the fact that the Department of Chemical Engineering soon moves to a new building on the Ohio State campus is given to his planning and foresight. Koffolt is a charter member and past chairman of the Central Ohio Section of A.I.Ch.E., and was elected to his present post of director of the Institute in 1956.

Presentation of the award was made by Robert S. Curl, president of Columbus Technical Council, at a dinner attended by 250 members of the Council, and held in observance of Engineers Week.

Clifford E. Oman appointed Tuscola general manager for U. S. Industrial Chemicals (National Distillers). He moves up from the position of assistant manager of the petrochemical plant in Tuscola, Illinois.

Clyde Williams, president of Clyde Williams & Co., named recipient of the James Douglas Gold Medal of the American Institute of Mining, Metallurgical and Petroleum Engineers. This specific citation is for "outstanding contributions in nonferrous metallurgy . . . particularly through stimulating research . . . and use of both common and less common metals."

N. H. de Nevers has accepted a position as research engineer with California Research. He recently completed work on a Ph.D. at the University of Michigan.

Elton Soltes takes over the position of manager in special projects at the Dallas headquarters of Delhi-Taylor Oil, Special Projects and Exploration Division.

C. Gene McGlone becomes research supervisor in Research and Development Division of Du Pont's Polychemicals Department at the Sabine River Works, Orange, Texas.

continued on page 144

people in management & technology

continued from page 142

William P. Gee elected vice president of the Texas Co. in charge of foreign petrochemicals. Gee joined Texaco in 1927 as a research chemist, and was, until his recent appointment, president of Texas-U. S. Chemical. **Arthur O'Keefe** moves into his position as president of the firm, which is jointly owned by Texaco and U. S. Rubber.

Walter H. Zinn elected vice president of Combustion Engineering, in charge of nuclear power activities. The firm recently acquired General Nuclear Engineering Corp., organized and headed by Zinn, as a subsidiary. The first director of the AEC's Argonne National Laboratory, Zinn is also a pioneer in the design and building of nuclear power reactors.

David K. Eads joins Foster Grant Co. as supervisor of the chemical engineering process development section of the research laboratories in Leominster, Mass.

James K. Rice steps up into the post of president and general manager of Cyrus Wm. Rice & Co., Pittsburgh consulting engineering firm.

Calvin A. King elected president of Bird Machine Company. King was previously in charge of the Bird Research and Development Center.

Robert A. Beall, 38 year old Department of the Interior Scientist, recipient of an Arthur S. Flemming award, given annually to outstanding young men in the federal government. Beall, who heads the Melting Lab. at the Bureau of Mines' Experiment Station in Albany, Oregon, is recognized as a world authority on the consumable electrode arc-melting technique. He also received the meritorious Honor Award of the Department of the Interior.

Another of the ten winners of the Arthur S. Flemming Award is **Alan Lovelace**, senior project engineer at Air Research and Development Command's Center at Dayton, Ohio.

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Rolf V. Wallin (left) appointed vice president engineering, Union Carbide Chemicals. Wallin joined Union Carbide in 1933, and has been with the firm ever since, most recently as director of engineering. The company also named **Robert W. King** director of engineering, with offices at South Charleston, West Va.

John T. Pinkston moves into the newly created position of process consultant of United Engineers & Constructors, Philadelphia. Pinkston, who holds six patents and has published technical papers dealing with developments in petroleum refining and chemical processing, will be in charge of process development activity for the firm.

Karlis F. Riskevics is an addition to the staff of Allis-Chalmers Atomic Energy Division. He holds the post of assistant engineer in the materials and chemical section.

Chemetron (Chemical Products) has promoted **John P. Haggerty** to general manager of Crestwood Chemicals. Headquarters are in Newport, Tennessee.

Roblee B. Martin named general manager of the new Dundee Cement Co. plant now under construction at Dundee, Michigan.

Robert W. Pressing appointed general manager, New Products Department, Linde Company (Union Carbide), with offices in New York City. He was formerly manager of molecular sieves production and development, Tonawanda, N. Y.

Emile C. Freeland appointed chemical engineering adviser to the United States Operations Mission. He is stationed in Tel Aviv, Israel.

Thomas K. Sherwood lectures at the annual Priestley Lecture Series sponsored by Phi Lambda Upsilon. Sherwood, who is professor of engineering at M.I.T., speaks on *Phase Transfer Equilibria.*

continued on page 146

continued from page 145

Mervin J. Kelly retired recently as chairman of the board of directors of Bell Telephone Laboratories, after 41 years with the company. Kelly's contributions have been not only in research and development programs relating to communications, but also in projects for the armed forces. He was awarded the Presidential Certificate of Merit in recognition of his contributions during World War II. Since then, Kelly has held posts with the AEC, and Departments of Defense and Commerce. A member of the board of directors of Bausch & Lomb, he will serve as consultant to the company after March 1. A.I.Ch.E. and Bell Laboratories have established an annual award for achievement in the field of communications to honor Mr. Kelly upon his retirement. Known as the Mervin J. Kelly Award, it will consist of a bronze medal, a certificate, and a cash stipend of $1000. Kelly continues as chairman of the Industry Campaign of the United Engineering Center Building Fund.

Donald L. Katz, president of A.I.Ch.E. is one of the authors of the recently published *Handbook of Natural Gas Engineering.*

General Electric named **Jerome T. Coe** (left) general manager of the Silicone Products Department at Waterford, N. Y. He succeeds **Charles E. Reed,** who becomes general manager of GE's Metallurgical Products Department. Both Reed and Coe have been associated with the company's silicone operations since 1942.

Metal & Thermit Corp. has placed the Coatings Division under the general managership of **Donald W. Oakley.** Oakley, with M&T since 1947, is past chairman of A.I.Ch.E. New Jersey Section, and is currently on the national program committee.

Homer A. Smith appointed assistant manager, chemical distributor operations, Minerals & Chemicals Corp. of America. Plant is in Menlo Park, N. J.

people in marketing

Bruce Alexander appointed to the position of manager of advertising and marketing services at Blaw-Knox. Alexander transfers to Pittsburgh from the company's Chemical Plants Division, where he has served in various sales promotion capacities.

Gregory J. Siragusa joins the Wilson Meyer Co. as Northwestern representative. With territory including Oregon, Washington and Montana, and several Canadian provinces, Siragusa will be responsible for service to Eastman Chemical Products customers.

Jules Gilbert assumes post of market research analyst at Hooker Chemical. His field is phosphorus and its derivatives.

James V. Roy becomes sales manager of Singmaster & Breyer, N. Y. affiliate of Fluor Corp., Ltd., in Los Angeles. Roy, previously sales engineer for Blaw-Knox, was project engineer for Singmaster & Breyer on a Boron-10 isotope plant designed for AEC.

R. A. Jones named sales manager, molecular sieves, at Linde Co. (Union Carbide) in New York City. Jones has held several positions with the company since joining it upon his graduation from the University of Iowa in 1942.

John C. Nettleton promoted to sales representative, Industrial Chemicals Division, Stauffer Chemical. His offices are in Akron, Ohio.

NECROLOGY

William S. Brackett, 60, vice president of engineering for Union Carbide Chemicals (Union Carbide). Brackett had been associated with Union Carbide since 1923. He was a charter member of the Charleston Section, A.I.Ch.E.

Robert Van Cauwenberghe, president of the Societe Royale Belge des Ingenieurs et des Industriels, in Brussels, Belgium.

F. C. Hettinger, visiting professor and chairman of the Department of Chemical Engineering at Johns Hopkins University until 1956.

Luther B. (Jack) Turner, 55, Enjay Co. expert on polymers and plastics. Turner had been with Enjay and other affiliates of Standard Oil (N. J.) for 27 years.

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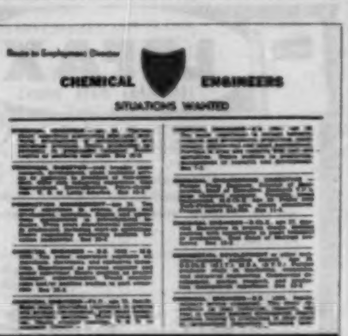
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A. I. Ch. E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members and Associate Members will receive careful consideration if received before May 15, 1959, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

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Cover, John A., *Beaumont, Tex.*
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Forienza, Gerard A., *New York, N. Y.*
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Shea, James J., *Idaho Falls, Idaho*
Young, Henry H., *Kansas City, Mo.*
Zaremba, Daniel E., *Beaver, Pa.*

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Beard, Sam J., *Richland, Wash.*
Bissett, James Sidney, *Arlington, Tex.*
Boadle, Robert, *Big Spring, Tex.*
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Burn, Peter, *Idaho Falls, Idaho*
Chenault, Roger V., *Houston, Tex.*
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News and Notes of A.I.Ch.E.

Nominating Committee – The Nominating Committee for 1959 is headed this year by Past-President George Holbrook. On the Committee with him will be L. C. Kemp, Jr., of the Texas Company; J. G. Knudsen of Oregon State College; R. A. Morgen of Purdue Research Foundation; H. F. Nolting of Standard Oil (Indiana); C. W. Swartout of Mallinckrodt; and Lee Van Horn of Fluor.

For Local Sections wishing to send suggestions to the Nominating Committee or to back a petition, here is the all-important schedule that must be met if their candidates are to get maximum publicity. The By-Laws of

A.I.Ch.E. require that the Nominating Committee complete its slate of officers and directors at least 20 weeks before the Annual Meeting in order that the condidates may be publicized in *CEP*. The Nominating Committee's suggestions will be submitted, therefore, by July 18 and will appear in the August issue of *CEP*.

Although the Constitution requires that nominating petitions be received in this office not later than 9 weeks prior to the Annual Meeting—or by October 3—my advice to all sections considering backing a favorite candidate by a petition is to try, in fairness to the candidate, to get biographical data, picture, etc., along with the petition signed by the required 50 members, into A.I.Ch.E. headquarters not later than July 15. Otherwise there can be no guarantee that the nominees by petition will appear in August with the candidates selected by the Nominating Committee.

Student to Associate—Frank Conrad, Professor of Chemical Engineering at the University of Missouri School of Mines and Metallurgy in Rolla, follows up his recently graduated students who have not applied for membership in A.I.Ch.E. with a personal letter in which he reminds them of the waiving of entrance fees for former student members who wish to become associates and of the advantages to a professional man. He also encloses a questionnaire that enables the school to collect some personal data on the new graduates.

Indianapolis Section—Welcome to the brand-new Indianapolis Section, recently granted Local Section status by Council. The new section, by the way, has almost achieved its quota in the Members Gifts Campaign—91%.

More Unity—Recently we were given an excellent example of how closely the engineering societies are working together these days. W. C. Osborne, chairman of the A.S.M.E. Committee on Pumps, observed that the contributions of Bob Jacks, chairman of A.I.Ch.E.'s Pumps Subcommittee and of the group which is responsible for a manual on pumps that we hope to publish this spring, have "resulted in a code that is technically more sound and manifestly more acceptable to both professional societies."

Directory—We expect to have a new Directory in April. This will be distributed to all Local Section officers, Student Chapter counsellors, and committeemen of A.I.Ch.E. No general distribution to the membership is planned, but we urge those who wish copies to drop us a letter or post card, and we will see that the Directory is sent to them as promptly as possible after publication.

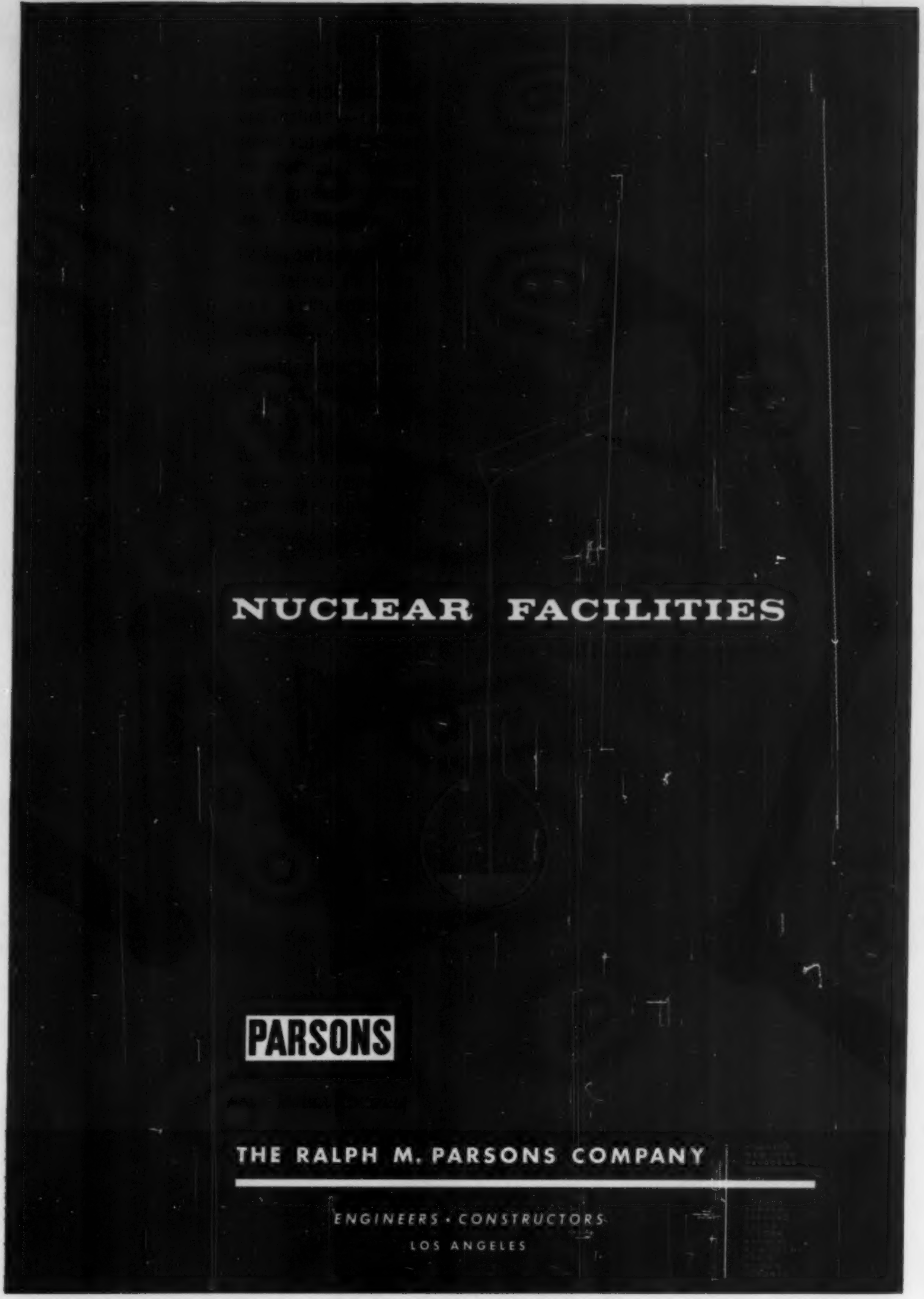
Council Actions—Look for more information and developments on the following recent important decisions of Council:

1. *Appointment of a Chemical Engineering Study Committee,* which will investigate the present position of chemical engineering relative to other engineering disciplines, to determine what chemical engineering should be in the future and what A.I.Ch.E. can do to bring about desirable changes. President Katz is now deciding on the make-up of the committee and is writing a preliminary outline of its task.
2. *Approval of E.J.C.-E.C.P.D. amalgamation.* A special study group of the two organizations brought in a preliminary plan for amalgamation, which has been approved by A.I.Ch.E. Much work is still to be done, however, since the plan offers only a very broad outline.
3. *Sponsoring of New Film Strips.* M. W. Bredekamp, Chairman of the Chemical Engineering Education Projects Committee, received approval from Council for the production of film strips on theoretical subjects in chemical engineering.
4. *Publication Reciprocity with A.S.M.E.* Members of A.I.Ch.E. will now be able to subscribe at member rates to the new *Journal of Heat Transfer* published by A.S.M.E.; in return members of A.S.M.E. may purchase our Symposium Series volumes on heat transfer at our member rates.

Liaison Responsibilities – Last year each member of Council was delegated certain liaison responsibilities to committees and Local Sections. A statement detailing the philosophy of this plan will soon be sent to the chairman of each Local Section and committee, and it will be included in

the Handbook of the Local Sections, now being modified by Jerry McAfee. Essentially, each member of Council is asked to act as a vice-president in charge of a designated area of responsibility and is expected to review committee and Local Section reports of the past several years, to inspire the performance of the committees and the Local Sections, and to see that problems arising during the year which require Council attention or action are given the necessary hearing before Council. Every committee and Local Section chairman has been informed as to who his liaison member is and is urged, should any questions arise, not to hesitate to write to him or to the national headquarters.

F.J.V.A.



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